AD-A185 292 WARRANTIES FOR WEAPONS: THEORY AND INITIAL ASSESSMENT 1/2
(U) RAND CORP SANTA MONICA CA J P STUCKER ET AL
APR 87 RAND/N-2479-AF F49620-86-C-0008

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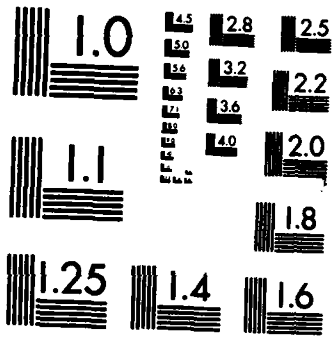

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A RAND NOTE

Warranties for Weapons: Theory and Initial Assessment

James P. Stucker, Giles K. Smith

April 1987

RAND

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

A185 292

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER N-2479-AF	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Warranties for Weapons: Theory and Initial Assessment		5. TYPE OF REPORT & PERIOD COVERED Interim
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) James P. Stucker, Giles K. Smith		8. CONTRACT OR GRANT NUMBER(s) F49620-86-C-0008
9. PERFORMING ORGANIZATION NAME AND ADDRESS The RAND Corporation 1700 Main Street Santa Monica CA 90406		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Requirements, Programs & Studies Group (AF/RDQX) Ofc, DCS/R&D and Acquisition Hq, USAF Washington DC 20330		12. REPORT DATE April 1987
		13. NUMBER OF PAGES 90
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

No Restrictions

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Guarantees
Weapon Systems
Contracts
Military Procurement

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See reverse side

DD FORM 1 JAN 73 1473

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Warranties have been selectively applied to weapon systems acquisition over several decades. However, in 1983 Congress passed the first law requiring that military contractors provide warranties on all major weapons sold to the Services. Such blanket application raises issues both of tailoring warranties to the wide range of weapons and acquisition environments and of proper implementation policy and procedural guidelines. This study concludes that warranties can have a positive effect on selected acquisition programs. Analysis of pre-law warranties suggests that factors contributing to warranty success include: specific, easily measurable objectives; explicit contractor incentives and remedies; explicit government duties; and reasonable prices and expectations. An initial survey of post-law warranties, however, reveals that many warranties do not appear to adequately detail either their objectives or the remedies to be applied if those objectives are not met.

A RAND NOTE

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Warranties for Weapons: Theory and Initial Assessment

James P. Stucker, Giles K. Smith

April 1987

Prepared for
The United States Air Force

RAND

PREFACE

Although warranties have long been a common part of commercial business practice, until recently they were applied only occasionally to military products, and usually only to those with close commercial counterparts. Then Congress passed the Defense Appropriations Act for 1984, since modified by the Defense Authorization Act of 1985, requiring the Services to obtain warranties on *all* major buys of *weapon systems*. The effects and implications of that legislation are only beginning to be understood.

Can warranties help in improving weapon cost, schedule, performance, and reliability? The Air Force and the other Services currently are spending a lot of money and effort specifying, negotiating, implementing, and enforcing warranties, without much information on whether this is all worthwhile. Major limitations include the evaluation of past and ongoing warranties, the institutionalization of knowledge concerning what works and what does not, and the training and knowledge of incoming project management personnel.

A more basic problem concerns the inability of project managers, program evaluators, and Air Staff policymakers to effectively communicate their ideas and experiences on warranty issues. Warranty definitions contained in the Federal Acquisition Regulations, in the 1984 and 1985 laws, and in subsequent DoD and Air Force guidance directives are so broad that reasonable and well-intentioned people can, and consistently do, fail to communicate.

This Note attempts to fill that void in four ways. (1) It presents a simplified theory of warranties designed to provide insights into the basic concepts, interrelationships, and possibilities of military warranties. (2) It suggests a taxonomy for military warranties. (3) It presents a simplified listing of alternative objectives for different kinds of warranties and of the possible tasks that a contractor may be required to perform. And (4) it recommends how the Air Force might better understand and evaluate warranties and disseminate that knowledge. These definitions and discussions should be of interest to industry and Service personnel who work with or oversee warranties.

This work was performed as part of the "Methods and Strategies for Improving Weapon System Reliability and Maintainability" Project within the Project AIR FORCE Resource Management Program. That project is sponsored by the Air Force Special Assistant for Reliability and Maintainability.

SUMMARY

During the 1970s and early 1980s, the Services negotiated warranties on selected weapon subsystems, expressing satisfaction with some and citing problems with others. Then in 1983 Congress passed the first of several laws requiring that military contractors provide warranties on *all* major weapons sold to the Services, apparently believing that commercial experience with warranties, along with the several military successes, indicated that warranties could increase the chances that new weapons would perform satisfactorily.

Many people, however, question the value of warranties and the idea of applying them across the board to all weapon acquisitions. They especially reject the idea that warranties are a panacea for acquisition problems and will by themselves dramatically improve the quality and performance of weapon systems. This study suggests some initial answers to parts of that controversy.

We suggest that **warranties for weapons differ fundamentally from warranties for commercial products** and even from military warranties for commercial-like products: The products differ, the market environments differ, and the acquisition processes differ. Weapons are typically more complex, risky, and expensive than other products. Only the government purchases major weapon systems, and only a small number of large firms produce them. Furthermore, the governmental buyer usually initiates these acquisitions and controls and directs them throughout the acquisition stages. Thus the effectiveness of warranties for weapons must be evaluated directly rather than by reference to commercial analogies.

We suggest that **warranties for weapons should be directed toward the availability, reliability, and maintainability of new weapons**. During pre-production, production, and acceptance testing, the government can verify most of the performance attributes of the systems (how fast they can fly, how far they can distinguish targets, how straight they can shoot, etc.). However, it is usually much harder to measure availability--how long the weapons will operate at a satisfactory

performance level (their reliability) or how difficult they are to fix (their maintainability). Such attributes must be observed over long periods of time and under actual field conditions. Warranties can tie the *actual* field performance of new weapons to the ultimate profit and reputation of its builder. This advantage is the primary reason why warranties hold promise for improving traditional acquisition contracts.

This Note examines warranties written on the availability or performance of new weapon systems. It recognizes, however, that warranties can also contribute to lowering the life-cycle costs of new weapons. In fact, reducing support costs appears to have been the *raison d'etre* for many military warranties. This is unfortunate, because our theory suggests that **selecting the levels of availability, reliability, and maintainability that minimize peacetime life-cycle costs (given the desired level of performance) typically yields too little availability, hence less combat effectiveness than was available within the original budget.**

We reviewed two sets of warranties, one set written before the laws were passed and a second set written since January 1, 1985, and complying with the most recent law. Analysis of the earlier warranties suggested that **at least four factors contribute positively to warranty success**:

- **Specific, easily measurable objectives;**
- **Simple, explicit contractor incentives and remedies;**
- **Simple, explicit government duties; and**
- **Reasonable prices and expectations.**

We also note a major problem with the incentives provided by several of the older warranties. Most of those warranties applied to fielded systems and were written to require depot repair and other support activities. The warranties were seen as vehicles for both purchasing interim contractor support and for contractor incentives to improve the reliability as well as maintainability of his system, because the less it failed the fewer resources he would need to apply in fixing them. Most of the warranties urged the contractor to remove deficiencies in his product by adopting "no cost" reliability-enhancing engineering change proposals (ECPs) whenever he found it cost-effective to do so. However, many of the warranties also prescribed so many additional "no cost" duties whenever a product-improving ECP was approved that the contractor seldom found it profitable to prepare ECPs.

Study of the second set of warranties, those written to comply with the 1985 law, revealed some interesting contrasts with the earlier warranties. In particular, two major attributes that contributed to the success of earlier warranties are missing from a large number of the newer ones: the simple definition of measurable objectives and the precise, prespecified remedies expected of the contractor. We suggest that such **nonspecificity can easily lead to misunderstandings and possibly to threats of nonperformance and litigation**.

Are warranties for weapons worthwhile? The jury is not in yet. We suspect that there are selected applications where the intelligent use of warranties can and should increase the probability of achieving the weapon's availability goals and reducing life-cycle costs. However, warranties remain novelties as far as the Services are concerned. Despite the substantial experience base that was surveyed in this study, the results of past warranty programs have not been systematically examined for lessons learned. Few program personnel understand their possibilities and fewer still appreciate their pitfalls. **We recommend that the Air Force**:

- **Reexamine, in more detail than was possible in this study, the evidence and experience available from past and current warranties to verify whether the factors identified are actually major contributors to program success.**
- **Compile detailed and comprehensive information on all current weapon warranties, so that analysts will eventually be able to evaluate the outcomes of these wider-ranging applications.**

Uncertainty and misunderstanding remain about how to draft a warranty: how to select and specify the objectives, how to structure the incentives, how specific to make the remedies. Additional data and further analyses are needed before future program managers will be able to more intelligently use, or waive, warranties.

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I. INTRODUCTION

BACKGROUND

During the 1970s and early 1980s the Services negotiated warranty clauses on selected procurements, usually for electronic items and subsystems. Then Congress passed the Defense Appropriations Act for 1984, since modified by the Defense Authorization Act of 1985, requiring the Services to obtain warranties on all major buys of weapon systems.

Congress apparently passed those warranty laws as one proposed solution to what most people view as a very real problem: Some of the new Air Force, Army, and Navy weapons do not work as well as they should. One aspect of the problem concerns the failure of some new weapons to fully achieve the contractually specified levels of functional performance (their ability to conduct the specified mission, such as aircraft range, missile accuracy, etc.). Recent publicized examples include the Army's Sgt. York air defense gun, which could not track and hit targets as well as it was supposed to, and the alleged deficiencies in the B-1 countermeasures set. Performance shortfalls considerably degrade the value of weapons.

A second major aspect of the problem is that even when a system checks out well in the labs, and even when it passes acceptance tests, we still cannot be sure that it will function satisfactorily *over time* after the Service accepts it. Availability as a function of reliability and maintainability--the ability of a complex product to work continually (or, for other types of systems, to work on demand) in its intended operating environment when operated and serviced by ordinary servicemen--has proved especially difficult to predict and control.

Traditional acquisition policies don't really try to demand specific availability, reliability, and/or maintainability *in the field*. The contracts may specify target availability levels, but the weapon system is seldom tested long enough or realistically enough to verify that those levels have been achieved. Without such testing, there is no practical way to enforce specifications for actual field availability, and the typical shortcomings are a logical consequence.

Warranties for military weapons are one proposed method for dealing with these problems. We are accustomed to commercial warranties, to the idea of getting a warranty whenever we buy an appliance or a new car. And many of us believe these commercial warranties work, that they are cost effective. But military warranties are newer. The first question normally asked is: can the commercial concept be applied productively to military products?

The military does buy some products that are like commercial products and have low levels of uncertainty and risk, and it is logical that warranties similar to those for commercial products can be applied more or less directly to those products. Major military weapons, however, are different, for at least three reasons:

1. Most of the major weapons bought by the military are very advanced, complex, risky products that do not have counterparts in the commercial world. These weapons differ *in kind* from most civilian products.
2. The Services typically supervise and control the design and development of most major military acquisitions: The product is not uniquely the responsibility of the firm that develops and produces it, and that firm is usually not in a position to take full responsibility for the design.
3. Military products are frequently ordered into production long before their test programs are completed and certainly long before their availability, reliability, and maintainability characteristics can be fully validated. The Services typically deem this early introduction of advanced weapon system into the operational force well worth the consequent risk of subsequently discovering problems in the design.

Because of these differences between commercial products and weapons, we believe that the purpose of providing warranties for them also differs. Commercial firms typically give warranties on commercial products as a form of "non-price competition"; they issue particular warranties to distinguish their products from similar ones and to provide an additional attribute of choice for the consumer. For example, we may buy a wrench at Sears rather than another store because the Sears wrench comes with an unqualified warranty. If we break the wrench, we can take it back to any Sears store and they will give us a new one--no questions, no forms to fill out affirming that we used it in a normal way, etc. That is one example of a commercial warranty; such warranties are easy to write and manage, and for many things they are quite adequate. But for a weapon system those warranties are not enough. If we give a soldier a wrench for use in taking apart his gun when it jams and the wrench breaks, a commercial warranty is useless. The soldier needs a warranty that will give him *high assurance that the wrench will not break* and even that the gun will not jam. Likewise, a fighter aircraft pilot needs a warranty that raises his confidence that his radar and his afterburner will achieve their expected levels of performance when he needs them. The objective of a *weapon* warranty generally should be to *improve the probability that the system will perform at a specified, acceptable level when it is needed.*

Thus, military warranties for major weapon systems should not be expected to be similar to commercial warranties. The questions of interest then become: "Are warranties for *weapons* worthwhile?" "How are they currently structured?" and "How should they be structured to improve their performance?"

WARRANTIES MANDATED UNDER THE 1985 LAW

The 1985 law calls for three types of warranties on all major weapon systems:

1. "The item provided under the contract will conform to the design and manufacturing requirements specifically delineated in the production contract;
2. "The item provided under the contract, at the time it is delivered to the United States, will be free from all defects in materials and workmanship; and
3. "The item provided under the contract will conform to the essential performance requirements of the item as specifically delineated in the production contract."[1]

[1]Title 10, Section 2403 of the United States Code.

The first two warranties refer to specifications; they warrant that the contractor will build the system to the design as defined in the production contract. The third warranty is the performance warranty, warranting that the contractor will deliver a product that works as promised.

The legislative history of the warranty laws does not make clear just what the major objective of Congress was in conceiving and passing the laws for performance warranties. On the one hand Congress apparently wanted to be able to blame the contractor if his new weapon system did not work, and to assess damages against him. On the other hand Congress seemed to believe that warranties would provide the contractor with incentives to build a product that would work as promised.

Nor does the history make a clear distinction between the functional performance of the weapon system--how high it can fly, how far, etc.--and the weapon's availability. Apparently both are candidates for inclusion in the "essential performance requirements" to be "determined by the Secretary of Defense to be necessary for the system to fulfill the military requirement for which the system was designed."[2]

We argue that military warranties should emphasize the availability, reliability, and maintainability of weapons--that warranties are generally *not* the appropriate instrument for insuring or improving functional performance.[3] And we will argue that military

[2] Ibid.

[3] The distinction we make between functional performance and availability is somewhat artificial at this time, but we find it useful in examining many situations where warranties historically have been used. It seems most practical when we are dealing with items that are reused (that can be examined and tested for different kinds of failures between periods of use); less useful when discussing expendable systems. For example, if a missile is launched and misses its target by more than the nominal distance, what happened? Was it a reliability failure, evidence of a functional limitation, or merely a member of the statistical population that is bound to fall on the outside of the circular error probability value? Cases like this remind us that although a definitional distinction between functional performance and availability is useful for expository purposes, it is much less important than the very real difference between weapon attributes that can be measured before acceptance and those that cannot.

warranties should act primarily as *incentives* to induce the contractor to build in improved availability, reliability, and maintainability--that merely applying penalties and placing blame are not desired outcomes for either party.

STUDY OBJECTIVES

Our study began by asking "Are warranties for weapons worthwhile?" However, we quickly encountered a multitude of problems: The data were too meager, the programs were too complex, the completed programs were too old, and the new laws changed everything; but perhaps most important, we quickly discovered that workers and officials involved with warranties had little or no agreement on objectives of warranties, on how the incentives contained in the warranties were supposed to work, or even on criteria for the ultimate evaluation of warranty or program performance.

Consequently, we established a more limited set of objectives:

1. To define a simple but integrated theory of warranties, the problems they are intended to address, and how they contribute to improving acquisition outcomes;
2. To provide a less formal but more practical discussion in which we categorize the full range of warranty types in terms of their objectives, the general strategy of achieving those objectives, and whatever other parameters seem necessary; and
3. To survey a modest set of military warranties to identify the minimum set of information needed to critically evaluate those or future warranties.

OUTLINE

Section II presents our analytic discussion of military contracts and warranties. Section III expands on that discussion and introduces important aspects of the current military warranty law and acquisition environment. Section IV then uses that general framework to discuss and analyze some of the older warranties. Section V does the same for a sample of recent warranties written under the 1985 law. Section VI presents observations on what we have learned and some conclusions and recommendations based on those findings. The appendixes contain backup material on warranty theory and on the warranties cited in Secs. IV and V.

Several organizations have drafted documents that provide guidance on the details of weapon system warranty preparation and administration.[4] However, broad policy-oriented statements of the concepts underlying military warranties and of the opportunities stemming from their use to improve acquisition outcomes are still absent. This Note examines policy issues, and it attempts to provide a foundation for that broader policy guidance.

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[4]See References 1, 2, and 3.

II. AN ANALYTIC FRAMEWORK FOR MILITARY WARRANTIES

A warranty is an assurance by the seller that his product will provide specified levels of service while in ordinary use by the buyer. Without a warranty of some kind, when the buyer accepts delivery of an item he is on his own; the seller has no further obligation for the performance, durability, or reliability of the product or for any other aspect of how it performs.

This section provides a brief analytic framework for military warranties and explains some of the purposes and practices of these warranties.[1] We view warranties as part of a general acquisition strategy, pointin out where, in theory at least, they might be useful in improving acquisition outcomes. The material in this section forms the foundation for the remainder of this Note and will be referred to frequently in the following sections as we describe, classify, and analyze particular kinds of warranties.

We will discuss the major rationales for warranties, illustrate the difficulties of contracting for availability (or any type of reliability and maintainability), and then show how several types of warranties address those problems. First, however, we discuss the basic tradeoffs between functional performance and availability and point out how the common practice of simply aggregating acquisition and support costs to determine the preferred level of reliability, maintainability, or availability is inappropriate because it typically results in lowered levels of combat effectiveness.

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[1]The concepts, discussions, and arguments presented in this section are based on interpretations of the literature on contracting and warranties, meetings with government and corporate personnel, and continued discussions with our colleagues. The most useful published sources include Refs. 4, 5, and 6.

ACQUISITION OBJECTIVES: FUNCTIONAL PERFORMANCE AND AVAILABILITY

The major tradeoff in weapon system acquisition is among functional performance, availability, and cost. As noted earlier, by *functional performance* we mean how well the system functions as intended: missile accuracy, aircraft range and speed, etc. By *availability* we mean the overall reliability and maintainability characteristics of the system (how long a weapon will operate at a satisfactory level of performance, and how difficult a weapon is to fix), usually expressed as a probability or a percentage.

Both functional performance and availability should be considered types of performance: both are valuable, both contribute to the combat effectiveness of the weapon, and both usually are costly. Furthermore, for a constant level of overall system cost, improvements in one of these areas frequently can be traded against decreases in the other. The task for program managers is to find the combination of functional performance and availability that maximizes combat effectiveness within the budget constraint.[2]

Too often availability is given insufficient priority. Early in the acquisition process, program managers usually specify preferred levels of both functional performance and availability. But later, when contracts are written and especially when support decisions are being made, the target levels of functional performance remain as priority goals while reliability and maintainability, the main constituents of availability, become simply tools for minimizing peacetime life-cycle costs.

Figure 1 represents this situation in a very simplified manner. For a hypothetical weapon, it shows the system acquisition costs, the system support costs, and their sum the system life-cycle costs. These curves show how costs vary with the amount of availability built into the weapon and are drawn presupposing that the preferred, specified level of functional performance will be realized. Acquisition costs typically increase as more reliability and maintainability (R&M) are

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[2]Appendix A provides a formal statement of this problem.

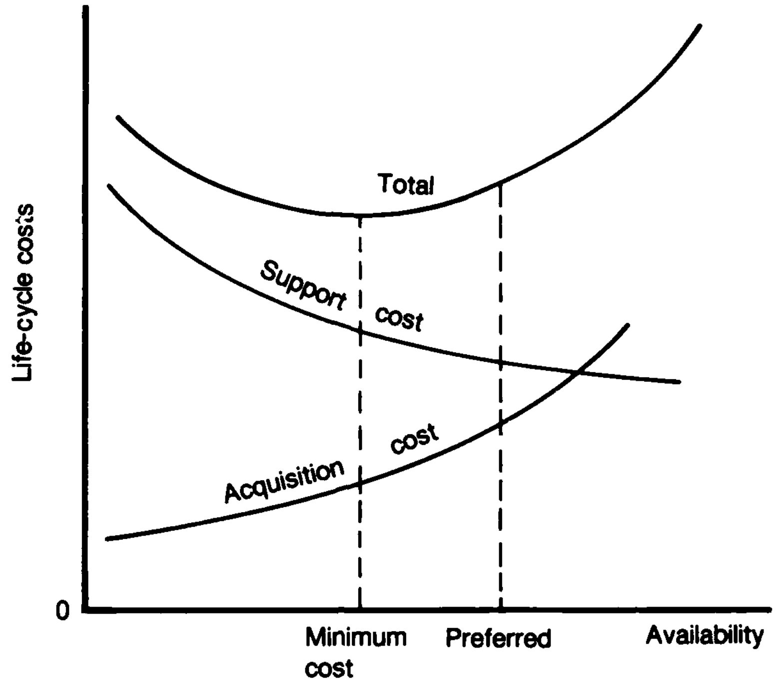

Fig. 1 -- Effect of increased availability on the life-cycle cost of weapon

built into the weapon and availability increases, while support costs typically fall with increases in R&M. This implies that the sum of the two component curves is probably U-shaped, first decreasing as availability improves and then increasing.

The preferred level of availability in Fig. 1 is represented on the rising portion of the total cost curve. This is the usual case. The preferred level of availability would never be on the falling portion of the curve because anyone who can get *more* of a good thing *for less money* will certainly do so. And, except for chance, it will never be at the low point of the total cost curve.[3]

[3] Appendix A outlines the tradeoffs among performance, availability, and cost and illustrates that in general the preferred solution will be where the improvement in combat effectiveness brought about by the last dollar spent for functional performance just equals the improvement brought about by the last dollar spent for availability.

Note that this approach differs fundamentally from simply minimizing the peacetime life-cycle costs associated with a specified level of functional performance (that is, selecting the level of availability described by the minimum point of the total cost curve). That approach is based on the assumption that availability does not contribute to combat effectiveness but only affects acquisition and peacetime support costs. That assumption is rarely valid for a weapon system.

Our talks with service personnel indicate that minimizing the peacetime life-cycle costs associated with a given level of functional performance is the predominant goal of many operational and support organizations, and also of the support-oriented personnel associated with program acquisition offices. This is unfortunate because, as Fig. 1 and Appendix A show, that approach typically yields too little availability and consequently an inefficient mix of resources resulting in less combat effectiveness than should have been achieved within the original budget.

RATIONALES FOR WARRANTIES

Identifying the preferred levels of functional performance and availability is just the first step in an acquisition program. Those levels must then be produced, and in most cases this involves the participation of a private contractor. The government's next problems are to indicate the type of product wanted and to induce the contractor to produce it, the goal being to achieve the desired product in a reasonably efficient manner. One important aspect of the process is to recognize the uncertainties and to deal with them explicitly, in a manner fitting the situation.

In a simple world with no uncertainties, where both seller and buyer knew what they could do and what they could expect from each other, contracting would be simple. The buyer would indicate that he desires a weapon with specified attributes and then negotiate with one or more sellers for its production. All parties would know how to produce it and what it would cost, so the negotiations would be simple and quick; the seller would produce it, make his profit and be happy; the buyer would receive it and be happy.

Figure 2a illustrates this simple world in a context that will be helpful in our later discussions. The contractor's development and production costs typically will increase if he devotes additional resources to the design, development, testing, and incorporation of availability-enhancing aspects of the product. In a world without uncertainties both parties would agree on the desired performance, the costs, and a reasonable profit for the contractor. The revenue then would be specified as point "a." When the contractor delivered the product with the desired specifications he would receive the indicated revenue.

Unfortunately, the world represented by this "take-it-or-leave-it," firm-fixed-price model rarely applies to major weapon systems. The acquisition of weapons is substantially more complicated for several reasons, including the nature of and need for the product, and the difficulty of predicting availability before the product is fielded.

Major weapon systems are special products: They are frequently expensive, take years to produce, and are needed for national defense. The buyer typically is depending on them and needs them in the field as soon as possible. Consequently, it is difficult for the buyer to

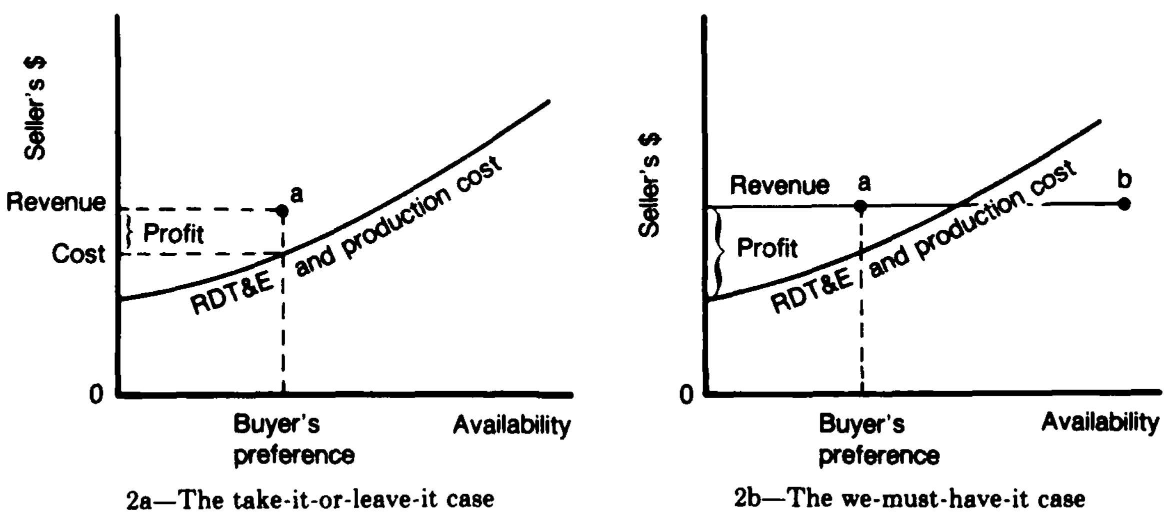

Fig. 2 -- The extremes of "fixed-price" contracting

abandon a project that he has supported for years, argued for before Congress, and allocated millions or even billions of dollars toward. It is difficult for the buyer to refuse to accept the product when it is finally delivered, even if its functional performance or availability is not up to par.

Some critics of the military acquisition process argue that instead of conforming to the firm-fixed-price acquisition model, the Services in fact just pay the seller full price for whatever he delivers, being willing to accept the weapon no matter how well or how poorly it works. They claim this is especially true for availability performance; if the weapon achieves all or most of its functional performance targets, major shortfalls in availability are routinely accepted. This is represented in Fig. 2b ("we-must-have-it" view) where the horizontal revenue curve indicates that the seller will receive the full price regardless of the availability he delivers. Given this guaranteed revenue and the rising costs of achieving availability, the seller tends to deliver the lowest acceptable level of availability, rather than the level contracted for, as that will maximize his profits.

Other critics of traditional acquisition procedures are less cynical of the government's role. These critics also believe that Fig. 2b accurately represents many situations, but they contend that the government accepts the lower level of R&M, not because it doesn't care or consciously decides to downplay availability but because it can't fully measure availability as it is being delivered. These critics, and we are among them, argue that for some weapons it is difficult or impossible to measure the delivered level of availability until the weapon is accepted and has been operated and repaired under actual field conditions by typical service personnel. This difficulty introduces one of the most important rationales for using warranties: to help the buyer achieve the full range of specified performance, including availability performance.

Achieving Specified Performance

The verification argument is the most straightforward justification for adding a warranty to the usual acquisition contract. This argument asserts that although the government may specify both functional performance and availability requirements to the contractor, it will in fact usually be able to verify receipt of only the functional characteristics at the time of product acceptance. And because acceptance normally terminates the seller's duties under an acquisition contract,[4] the common approach allows the contractor to fall short of meeting at least some of the availability requirements. Proponents of this argument expect the contractor to operate as suggested in the "we-must-have-it" model, Fig. 2b: He will increase his profit by delivering an acceptable, but less than specified level of availability.

Some availability attributes can be measured under controlled conditions before full-scale deployment; these attributes are sometimes called the weapon's *inherent* availability characteristics. If it were possible to accurately predict the field availability of the weapon from such tests, then availability performance could be contracted for and verified in the same manner as is functional performance. Proponents of the verification argument contend that all such predictions are at present very imperfect, so we need warranties.

The obvious remedy is for the buyer to impress upon the seller that he is going to test for availability even if this takes several months or even years longer than the traditional acceptance tests, and that the seller will not receive all of his revenues until this testing is complete and acceptable.[5] This is the essence of a warranty. Furthermore, the act of formalizing the field test and validation process helps to ensure that availability performance will receive a full measure of visibility and management attention.

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[4]Except for latent defects not observable at acceptance.

[5]This, in effect, reduces the revenue curve in Fig. 2b to the segment ab. Only if availability equal to or greater than A is delivered will the seller receive any revenue.

Managing Uncertainty

To achieve the verification goal requires that an appropriate business strategy be devised that explicitly deals with the uncertainties involved. A central aspect of such a strategy is contingency pricing.

During the acquisition of advanced weapon systems, both the builder and the buyer are often unsure that a product with the desired levels of functional performance *and* availability actually can be built within a specified cost and schedule. In these cases it makes little sense to specify precise performance "requirements" and a definitive price. When the chances of exactly achieving the requirements and costs are quite low, then the complementary chances of having to renegotiate and amend the contract or enter into some type of litigation are high. Under these conditions one option is for the buyer and seller to reduce some of that legal or contractual uncertainty by negotiating an acceptable *range* of performance and a *set of prices*, with the actual price to be based on the performance achieved.

This situation is shown in Fig. 3. In Figs. 2a and 2b the cost curve was assumed to be known with certainty; here we represent the producer's "expected" costs given the best information available to him and the buyer at the time the contract is negotiated. When uncertainties are present, however, the buyer and seller must allow for not attaining the preferred level of availability. If both parties agree that the uncertainty is small, they may still use a fixed-price contract specifying the preferred level of functional performance and availability. This gives all the risk (of needing to absorb higher-than-expected costs in order to meet the requirements) to the seller, and normally results in his insisting on a higher contract price so that there is some slack in his "expected" profits to offset at least a portion of any increased costs. For higher levels of uncertainty, however, the required price easily becomes so high that both buyer and seller prefer setting up a price schedule (or what is commonly called a cost-sharing arrangement).

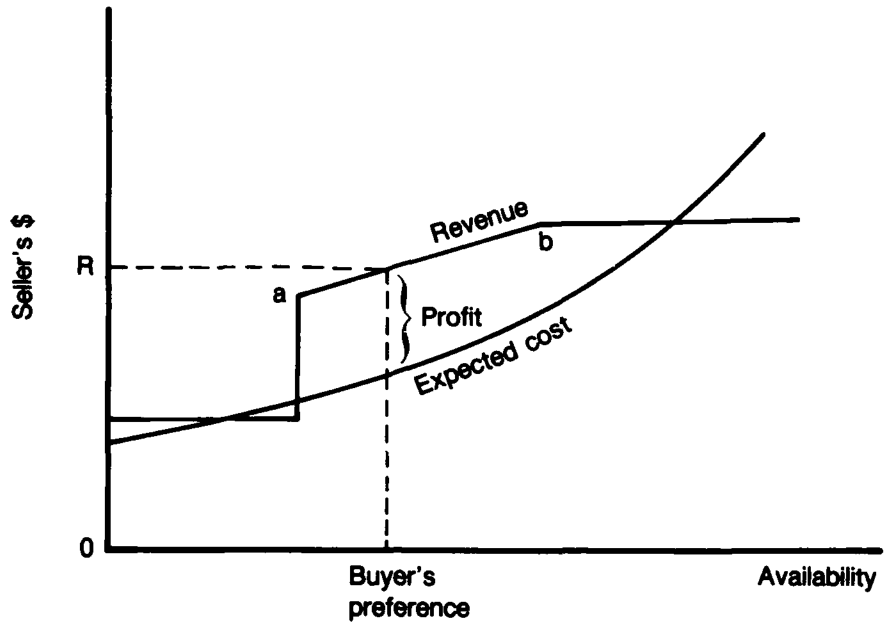

Fig. 3 -- Pricing under uncertainty

The revenue curve in Fig. 3 shows one, perhaps representative, pricing structure. The pricing schedule is set up so that the contractor's expected profits are maximized (the slope of the price schedule is equal to the slope of the cost curve) at the point of the buyer's preferred level of availability. However, the schedule also provides guidance for the contractor if that preferred availability does not turn out to be attainable at the expected cost.

The portion of the revenue curve between "a" and "b" represents the agreed-on tradeoffs among availability, revenue, and profits. If it turns out that during development or even during production the seller discovers that he will not be able to achieve the specified levels of functional performance and availability for the expected (target) cost, a pricing schedule of this type allows him to deliver a lower level of availability without losing all his profits or reneging on the contract. If, however, he discovers that he will be able to deliver more than the preferred availability, then the pricing schedule induces him to do so, provided the costs of producing that extra availability are less than had been expected.

Figure 4 amplifies these points. It shows the revenue function, the expected cost function, and two alternative realized-cost functions. If costs follow their *a priori* expectation the contractor can maximize his profits by producing A and receiving R. If, however, the performance turns out to be more difficult to achieve than expected, so that the actual costs are represented by the higher cost curve, then maximum profits are lower and are achieved at a lower level of availability, AL, where revenue is RL. If, the contractor achieves a "breakthrough," as suggested by the lower cost curve, then his profits will be maximized at the higher level of availability represented by AH.[6]

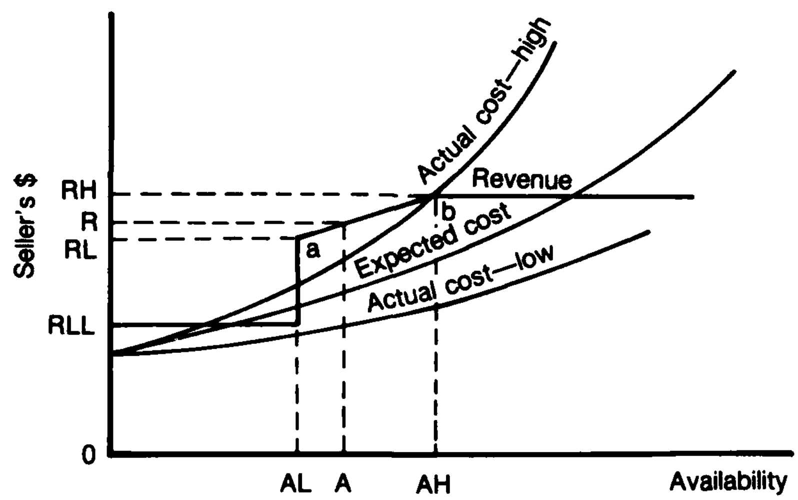

Fig. 4 -- Expected and actual costs, revenues, and profits

[6]In both of these examples the solution turns out to be at a knee of the revenue curve, but that is not necessarily the case, as examination of the figure will reveal. If the slope of the realized-cost curve is somewhere equal to the slope of the a-b segment of the pricing schedule, then that equality will indicate the point of maximum contractor profit.

In many acquisitions, the *de facto* arrangement for a major weapon system (even under a fixed-price contract) is that if the seller puts forth his best efforts and, through no fault of his own, fails to produce A > AL, he will still receive some amount of revenue, represented in Fig. 4 by RLL. Also, most acquisition offices have a limited budget and are not really interested in increasing the availability performance of the weapon *ad infinitum*. This situation is represented by the leveling of the price function at RH.

To summarize, a price schedule of this type performs two functions: it indicates the preferred level of performance given the initial information on costs and producibility by providing for maximum contractor profits at that level; and it indicates the agreed-on trade-offs between performance and cost in the event the contractor learns during development or production that actual performance and cost will differ from his expectations.

Figures 3 and 4 give some indication of the difficulties involved in pricing warranty or incentive contracts. Incentive pricing provisions can easily provide inappropriate or "perverse" incentives, especially when uncertainties are high. And, as we will see below in discussing reliability improvement warranties (RIWs), when the government attempts to provide the seller with incentives, not directly with a pricing schedule but indirectly by transferring selected costs to him, the difficulties multiply.

Strategies for Improving Efficiency

In addition to improving the chances of new weapons performing as they should, several other rationales are sometimes advanced for implementing military warranties. These can be grouped under the general headings of improving efficiency and shifting risk. We will discuss three of the efficiency arguments commonly used to justify warranties and then say a few words about shifting risk.

The tradeoff between acquisition costs and support costs is tied in with the verification argument. The selection of the preferred level of availability (and of functional performance) involves trading off acquisition costs for support costs. If the contractor is not impressed (by a warranty or some other method) that the government is really interested in obtaining a specified level of availability, he will tend to deliver less than that level and the life-cycle costs of the weapon may be higher than necessary.[7] Thus, warranties may be used to reduce life-cycle costs.

The tradeoff between contractor costs and government costs. Many proponents of warranties argue that the tradeoff between contractor costs and government costs can be improved, and life-cycle costs reduced, by the use of a warranty that includes initial contractor support (ICS) for the weapon. The contractor is often in a better position than the government to provide advanced diagnostic and repair actions during the first several years his weapon is in the field: He has a better understanding of the equipment, his personnel are already familiar with it, and he already owns and understands the test equipment. In addition, if a series of failures suggests that redesign actions are necessary, the contractor is better equipped to recognize the trend and to understand the necessary improvements. Thus, reducing support costs may require the participation of both parties. As we will see in later sections, ICS is the principal constituent of many past and current warranties.

The tradeoff between design costs and redesign costs is more complex. The argument for warranties here is that the sooner in the life cycle of a weapon the buyer tells the contractor that a specified level of availability is really desired and that tests will be conducted to see if it has been delivered, the better. The argument rests on the supposition that design costs are less expensive than the costs associated with redesigning the weapon after it has been delivered with less-than-desired availability: Early expenditures are more valuable and have a greater payoff than later expenditures.

There is a counter-argument, however, that considers the issue of uncertainty. Early in the program the contractor often has little idea of the availability his product will display, or of the costs of

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[7]But remember from Fig. 1 and the discussion in Appendix A that this is not always true, or desirable. Minimizing life-cycle costs, even given the preferred level of functional performance, will result in a less-than-preferred level of combat effectiveness.

increasing field availability from that level. Proponents of this view contend that it is often cost effective to allow the contractor to concentrate his initial efforts on achieving functional performance, which is usually considered both more important and more predictable than availability; and then, after the weapon is delivered, tested, and better understood, the contractor should attempt to improve its availability if that still seems desirable.

Both of these arguments probably have some merit. Many weapon-system acquisition programs contain large uncertainties, especially associated with the availability-performance parameters, so some compromise between design and redesign may often be beneficial.

Shifting Risk To Seller. One net effect of *any* nontrivial warranty is the shift of some uncertainty, and the consequent risk, from the buyer to the seller. Shifting of risk is a fundamental characteristic inherent in the warranty concept; it provides the incentive for the seller to improve the product and to produce and support it efficiently. Unfortunately, some people seem to view this transfer of risk as a primary objective of the warranty. They call it the "insurance" aspect of the warranty.

Insurance is the act of firming up ahead of time the consequences of some risky event. Often some event may or may not happen this year, but if it does the cost consequences are large. Insurance allows a person or an agency to tradeoff some smaller, known cost to protect against the larger possible loss. For example, if a person contemplates dying this year he can calculate the loss to his estate of his discounted future earnings; and an insurance company will, for a smaller but certain amount of money, agree to reimburse the estate for those forgone earnings if he should in fact die. Or a farmer may buy insurance knowing that bad weather may reduce the value of this crop. For a prepaid fee the insurance company promises the farmer he will receive full value for his crop whether it is damaged by the weather or not.

Buying insurance from the producer of a weapon system is similar. The buyer and the seller agree on a reasonable measure of performance for the product, perhaps an availability rate, a mean time between failures, or a specified number of false error messages. If this is an important measure, the buyer's operating and support costs may increase (perhaps by a large amount) if the target is not achieved. So the buyer may purchase a warranty from the seller saying that, if the required performance measure is not achieved, the seller will reimburse the buyer in some way. For example, the seller may promise (for the fee) that if his product does not deliver the required performance he will perform some prespecified acts, such as reducing his price, delivering more copies of the product, or redesigning it. The buyer is trading off some possibility of incurring large costs for the sure thing of paying a smaller amount. The seller is agreeing to accept this risk of possibly incurring the greater costs and possibly not, in return for the warranty price.* Some such arrangement is inherent in any warranty.

Risk shifting alone is seldom an appropriate or sufficient rationale for a weapon system's warranty, however, because it is rarely to the government's advantage to buy insurance from a commercial firm. Most analysts believe the U.S. government should usually self-insure: It has more resources than any firm and a better ability to survive losses, it has more projects under way at any given time and can better spread individual (and large) risks, and it is less risk-averse than the typical profit-motivated firms. We have seen no persuasive economic or political arguments in favor of the government's buying insurance.

Note also that any insurance purchased under a warranty is usually quite limited. The seller may assume responsibility for small fluctuations in costs or performance, but if large losses (or gains) occur he will typically be bailed out (or audited). Thus, limited cost-sharing arrangements that provide incentives for performance and for efficiency improvement and that reduce the risk of contract nonperformance are typically more effective, enforceable, and cheaper than large transfers of financial risk that attempt to insure the government against major performance shortfalls.

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*If the warranty is negotiated properly, its price will accurately reflect the amount of risk shifted to the seller. In commercial products the warranty price is often hidden in the product price, leading to the concept of a "no-cost" warranty. Many major appliances and automobiles, however, now offer additional warranty coverage for an additional, often substantial, fee.

TRADITIONAL WARRANTIES FOR WEAPONS

It may be helpful to demonstrate these elements of warranty theory by using them to illustrate several of the commoner types of warranties. We will discuss the so-called reliability improvement warranty (RIW), the logistic-support-cost (LSC) guarantee, and the mean-time-between-failure (MTBF) guarantee.[9] Then we will contrast those with the less common but potentially more promising availability warranty.

The Reliability Improvement Warranty

The RIW has been the most popular form of warranty used by the Armed Services since at least the early 1970s. Under it, the contractor assumes responsibility for repairing or replacing (as he sees fit) some specified portion or subset of the warranted units that fail during a specified period of time. Usually this means in practice that the contractor performs the depot repair function for the first several years his product is in the field. In other settings, such contractor activity is called interim contractor support. But ICS is usually performed on a piece-work or level-of-effort pricing arrangement, while the RIW must be a fixed-price contract. The difference between the RIW price and the expenses incurred by the contractor is his profit. This arrangement provides the contractor incentive to reduce his repair and replacement costs, perhaps even by improving the reliability (availability) of the product. The RIW may improve efficiency and it may improve performance; but, as we show below, it is a very clumsy instrument for inducing a contractor to deliver the "proper" amount of availability.

During the 1970s RIWs were usually applied to weapon procurements in which many of the items had already been delivered to the service and were in the field, often awaiting maintenance. This meant that the contractor faced tradeoffs between repair and redesign costs. More recently, warranties that are essentially RIWs have been written into the development contracts of selected weapon systems, allowing the

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[9]These warranties are discussed in many references. See, for example, Ref. 7.

contractor to plan ahead rather than simply react: In those programs he can trade repair costs off against both original design costs and later redesign costs. In either case the RIW approach can be illustrated by examining Figs. 1 and 5.

Figure 1 and the accompanying discussion illustrated how acquisition costs and support costs must both be considered in determining the preferred levels of availability performance and of total life-cycle costs for a weapon. The RIW approach attempts to simulate those costs for the contractor and thus to induce him to deliver the (buyer's) preferred level of availability. We illustrate this in Fig. 5.

The lower curves in Fig. 5 all refer to the contractor's costs; the upper curve represents total system costs brought forward from Fig. 1. The contractor's costs are composed of his development and production costs and the costs he incurs under the warranty. If neither the price of the acquisition contract nor the price of the warranty depends on the achieved level of availability, which is the normal situation under a RIW, then the contractor's maximum profit is achieved at the low point of *his* total cost curve. This level of availability may or may not coincide with the low point of the total system cost curve, or with the government's preferred level of availability. The actual outcome will depend on the relationship between the contractor's costs and the total system costs.

Under an RIW the government does not attempt to specify availability levels for the contractor. It instead transfers costs to him. This allows the contractor to select "his" preferred level of availability; it allows him to choose the profit-maximizing combination of design, production, repair, and redesign and retrofit costs; and it avoids many of the problems associated with specifying and measuring availability.

The RIW is not a very good method of inducing the contractor to provide the level of availability that the government prefers. Knowledge of the cost functions usually is too meager, and there is no particular reason to expect that depot repair costs will truly represent total support costs, especially if the contractor's costs are to be incurred only over the first few years of the program.[10] This

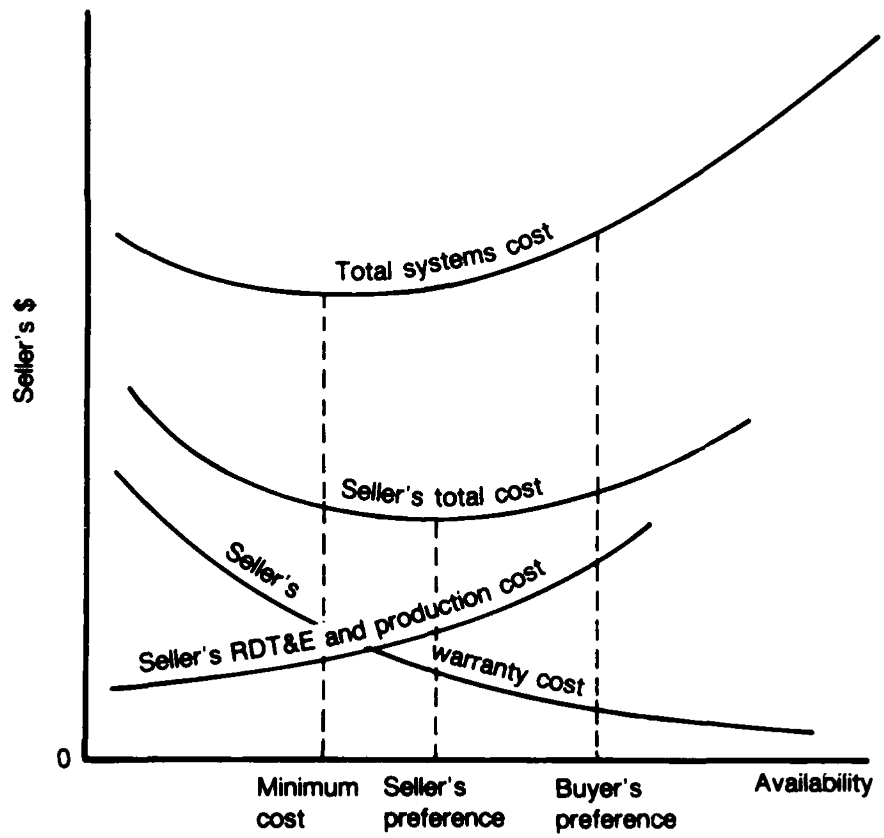

Fig. 5 -- Possible cost configuration under an RIW

noncorrespondence typically biases the contractor's solution toward temporary fixes rather than longer-term solutions.

To summarize, RIWs can provide real benefits to the buyer. They purchase ICS, and, as we have noted above, there are many reasons to believe that a seller can diagnose, repair, and support the system more efficiently than the buyer in its early years, and that the seller's immediate examination of failed items can contribute to faster and better redesign proposals. The fixed price of the RIW may induce

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[10]Many RIW contracts call for the contractor to provide additional spare parts, often including entire assemblies or even complete systems, whenever his repair turnaround time exceeds some target. This can possibly improve the correspondence between the contractor's warranty costs and the total system's support costs.

the seller to improve the availability performance of the product at least somewhat. Finally, RIWs do not require fancy field tests of availability, reliability, or maintainability. RIWs can then, at least in selected applications, lower total systems costs and increase availability. However, transferring costs to the contractor remains, at best, a clumsy way of indicating the government's desired level of availability.

The Logistic-Support-Cost Guarantee

The LSC guarantee differs from the RIW in a number of ways. With a LSC guarantee, the government can be more specific concerning the costs it wishes the contractor to consider, while still leaving the seller some freedom to adjust as his true costs are revealed. This type of warranty, however, does require more extensive field measurements.

The LSC guarantee is described at length in Ref. 7, p. A-120. The authors describe its three major elements as:

1. A target LSC defined in terms of a specified LSC model (requiring explicit reliability and maintainability inputs), which is estimated by the contractor.
2. An operational verification test, in which a measured LSC is computed using field reliability and maintainability data in the LSC model.
3. A positive and negative adjustment to the contract based on the verification test results in which the measured LSC is compared with the target cost.

Instead of just transferring selected, and probably unrepresentative, costs to the contractor as the RIW does, the LSC guarantee sets up a model representation of total support costs as a bogey and asks the contractor to meet or beat it. The pricing schedule is a recognition that uncertainty is present and allows the contractor options while retaining the incentives.

To the extent that this type of warranty accurately represents total support costs, it can be more effective than a simple RIW in providing incentives to the contractor to deliver an acceptable level of availability, and it is probably a practical approach in situations involving a large amount of uncertainty over the costs of achieving availability.

Specifying availability by means of the LSC model is a major advantage of this approach. This explicitly conveys the government's acceptable *tradeoffs* among the parameters, allowing the contractor a fairly large amount of freedom in designing the weapon. The major disadvantage is that this approach still focuses on the wrong objective. Support costs are only one element of life-cycle costs, and even successfully minimizing total life-cycle costs typically yields too little availability and combat effectiveness.

The MTBF Guarantee

This third common type of warranty is even more specific in the information it provides the contractor. It can be used directly to improve reliability rather than simply to reduce some aggregation of costs.

Like the LSC guarantee, an MTBF guarantee can be negotiated whether an RIW is in force or not, but they are usually found together. The MTBF guarantee emphasizes one (or more) aspects of the reliability or maintainability of a weapon. If the computed MTBF for a given measurement period falls below the guaranteed value for that period, the contractor must provide some or all of the following remedies:

1. Engineering analysis identifying the main failure modes.
2. No-cost (to the government) engineering change proposals.
3. Modification of existing units in accordance with the approved changes (at contractor expense).
4. Incorporation of the improvement in all newly produced units that come under the warranty.
5. Consignment spares for government use until the guaranteed MTBF is being achieved. These may become the government's property at no extra charge at the end of the warranty period if the guarantee is not met.

The MTBF guarantee alters the seller's *expected* costs so that they are minimized at the buyer's preferred level of reliability (or maintainability or availability). We illustrate this in Fig. 6. The contractor's costs again are composed of his expected development and production costs and the costs he can expect to incur under the warranty. The warranty costs are positive for reliability below the preferred level of reliability and become zero at that level. So long as the absolute value of the slope of the expected warranty-cost curve is greater than the slope of the expected production-cost curve, the seller's total cost curve will have a minimum at the preferred level of reliability.

This type of warranty thus can directly communicate to the seller the buyer's desire to achieve a specific level of reliability, maintainability, or availability. It is still clumsy, however, in that expected costs are being transferred and the government often may have little appreciation for the magnitude of the costs and risks it is asking the contractor to assume.

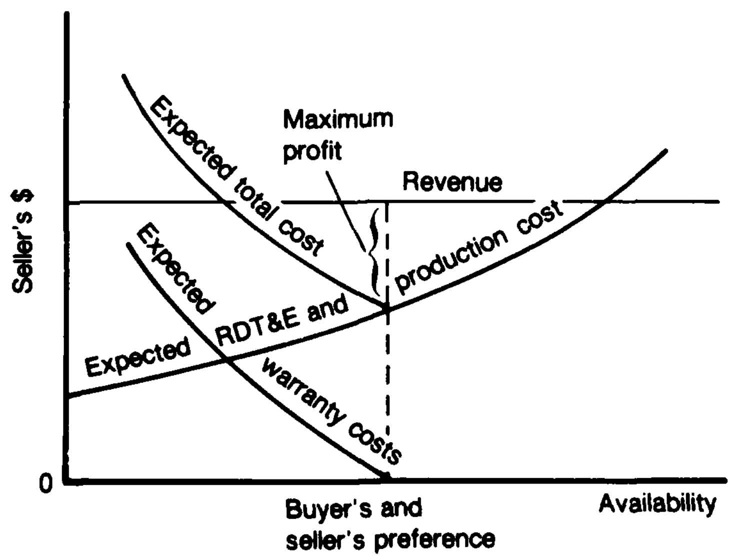

Fig. 6 -- The mean-time-between-failure guarantee

The MTBF guarantee thus is similar to the RIW and the LSC guarantee: All three detail costs for the contractor to consider in his design considerations; all three induce him to provide some amount of increased availability; and all three offer some revenue protection in case of unexpected difficulties (or opportunities). But the MTBF guarantee is also different from the other two: It has historically been quite specific in its application, calling for the attainment of one (or only a small number) of reliability or maintainability measures. This specificity limits the contractor's options and focuses his attention on those attributes of the weapon, perhaps to the detriment of other attributes.

The Availability Warranty

The availability warranty, or guarantee as it is sometimes called, has not been nearly as common as the other types of warranties, but we believe it is potentially much more interesting. Here the government explicitly negotiates availability levels for the weapon or its critical subsystems. Then pricing arrangements, as we depicted in Figs. 3 and 4, are negotiated in which the government and the contractor explicitly agree on the target level of availability and on acceptable revenue tradeoffs for shortfalls or breakthroughs. No costs need to be explicitly estimated or detailed in the contract. Sections IV and V discuss several warranties of this type that have actually been implemented.

SUMMARY

The major tradeoffs in any major acquisition are among functional performance, availability, and cost. Functional performance and availability contribute to the combat effectiveness of the weapon and are usually expensive. After the buyer has selected and specified the preferred levels of these parameters (typically during the concept formulation phase of the weapon's life cycle), procurement efforts should be directed toward achieving preferred functional performance *and* preferred availability levels, rather than the usual approach of first achieving functional performance and then minimizing life-cycle costs in a second-best attempt to improve availability.

In many cases the firm-fixed-price paradigm simply does not apply: Major acquisition programs usually contain large elements of uncertainty and urgency, major weapon developments are difficult to abandon, and major weapon deliveries, even if greatly flawed, are difficult to reject.

Field observation or verification is the essence of any warranty; a negotiated pricing schedule provides the most direct, easy to specify, and understandable incentives for effectiveness and efficiency.

Cost-based incentives, which specify tasks or "remedies" the seller must perform, are less direct but more prevalent in practice. For example, purchasing interim contractor support for a newly fielded weapon system may improve program efficiency, but using the ICS costs in a reliability improvement warranty to induce the contractor to improve availability is clumsy and difficult. An RIW may induce the contractor to deliver improved availability, but even if some way could be found to make the costs transferred to the contractor truly reflect the system's life-cycle costs, the RIW's cost-minimizing incentives would not necessarily guide the contractor to deliver the *preferred* level of availability.

A logistic-support-cost guarantee more directly alerts the contractor to a weapon's full support costs. Furthermore, by affecting the seller's revenue through contingency pricing, the buyer can indicate his preferred tradeoffs between availability and cost in the event the contractor learns during development or production that actual availability-related costs will differ from his expectations. But an LSC guarantee still focuses on minimizing support cost, typically inducing the delivery of a less than appropriate level of availability.

A mean-time-between-failure guarantee can directly alter the seller's costs so that they are minimized at the buyer's preferred level of availability, thus communicating even more clearly with the contractor than an RIW or an LSC guarantee. However, in situations involving more than nominal amounts of uncertainty, any cost-based approach is still inferior to a direct revenue-based approach.

Revenue-based warranty incentives are, in general, easier to specify, more effective, and more efficient than cost-based incentives. An availability guarantee relying on price-based incentives allows the buyer to directly specify a level of availability that appropriately includes consideration of how availability contributes to combat effectiveness.

Finally, even our "simple" diagrams indicate that when several types of warranties or other incentives for cost, schedule, or performance are combined, they may interact in diverse ways, and the incentives can easily become quite confused and confusing.

III. MILITARY WARRANTIES IN PRACTICE

Current military warranties are best understood by distinguishing among the different types of warranties and by placing particular warranties in the context of the overall acquisition cycle. This section constructs a framework for developing those two activities:

- First we outline a taxonomy of warranties, dividing them into two main types, each with two subtypes, according to their objectives;
- Next we discuss the phases of the acquisition cycle and how warranties fit into that process;
- Then we discuss the timing of particular warranties--the time within the acquisition cycle when the warranty contract is specified, negotiated, and signed;
- Then we introduce several of the common types of remedies--the tasks the contractor must perform if his product does not achieve its warranted objectives.
- Finally we present the simple matrix we will use to classify the sets of warranties discussed later.

WARRANTIES: A TAXONOMY

A military warranty is defined in Federal Acquisition Regulation Subpart 46.701 as follows:

> A promise or affirmation given by a contractor to the government regarding the nature, usefulness, or condition of the supplies or performance of services furnished under the contract.

This definition is so broad that reasonable people can, and do, consistently fail to communicate when discussing warranties; each has a different viewpoint and example in mind. The definitions in the 1985 laws are helpful but they also are vague, incomplete, and often confusing.

Military practice is no more helpful. The two most common forms of warranties cited in Service surveys are RIWs and MTBF guarantees--warranties that proclaim they will *improve* or *guarantee* reliability. But because we believe that all warranties should improve reliability and other aspects of availability and in many weapon system programs it is impossible actually to guarantee the attainment of any particular performance measure, we find both of those titles no more helpful than the all-too-familiar "no-cost" and "failure-free" warranties: None of these names adequately describes the essential features of a particular type of warranty.

The taxonomy of Fig. 7 provides a starting point for some useful naming conventions. It first groups all military warranties into two families: specification warranties and performance warranties. The warranties are then further described according to the kind of specification or the type of performance to be warranted.

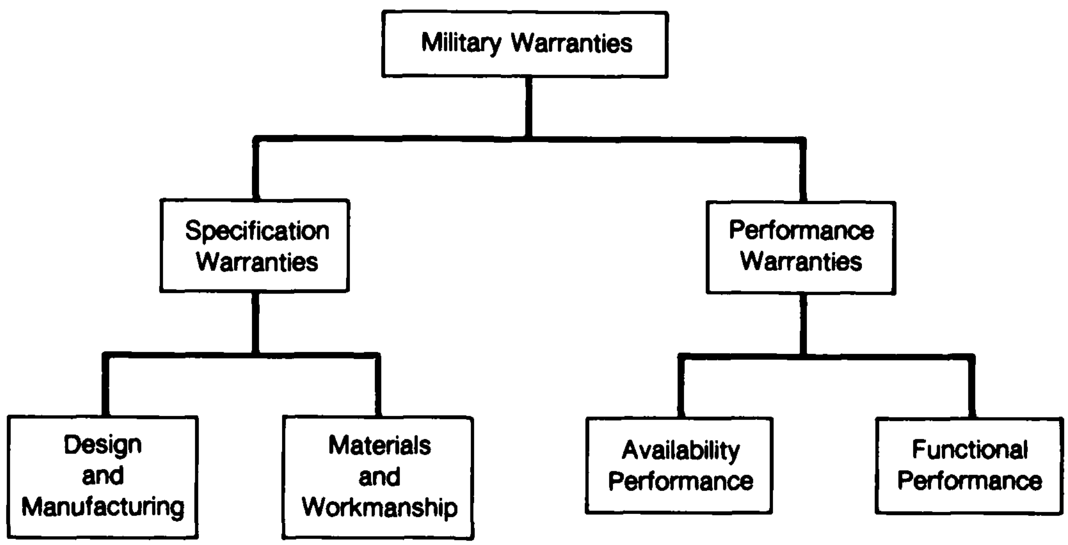

Fig. 7 -- A taxonomy of military warranties

Specification Warranties

Under a specification warranty the builder promises to construct the weapon according to all of the specifications contained or referred to in the production contract. The 1985 law breaks the specification warranty down into warranties for design and manufacturing and for materials and workmanship. In many cases it is difficult to distinguish between these different aspects of the specification warranty, but in practice that seems not be be too important.

Many people think that warranties of this type simply duplicate the functions of the correction-of-defects clause and the standard inspection clause that are found in most government contracts. Specification warranties may, however, supplement those clauses; they can help to define the time limit for discovering defects and to lessen the inspection requirements now assumed by the government. This area seems more suited to lawyers than policy analysts. Our interest is in the performance warranties.

Performance Warranties

We restate our working definition of a performance warranty:

> A performance warranty is an assurance by the seller that his product will provide specified levels of performance while in ordinary use by the buyer.

The phrase "while in ordinary use by the buyer" differentiates a performance warranty from other forms of acquisition contracts. A performance warranty focuses on the fielded performance of a weapon; or, stated somewhat differently, the objective of a performance warranty is to improve the chances that the seller will deliver a product that performs as promised.[1] The theory presented in Sec. II dealt exclusively with performance warranties.

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[1]Unlike specification warranties, performance warranties are required by law only in "mature" production lots--that is, those produced after the first year or the first one-tenth of the eventual total.

The law seems to treat functional performance (how high, how far, how fast, etc.) and availability as equally valid candidates for inclusion in "essential performance requirements." However, because functional performance can typically be validated during development tests, initial operational tests, or acceptance validation tests upon delivery, there is little need to warrant such performance. We believe that warranties are best limited to aspects of availability that cannot be so easily or quickly tested. Warranties are, in fact, possibly the *only* methods for ensuring that the contractor complies with the availability specifications of the weapon system.

THE ACQUISITION CYCLE

A second step in understanding the application of warranties to the acquisition process requires reviewing the major phases and documents of the acquisition cycle. Most major weapon system acquisitions go through the six major phases illustrated in Fig. 8. During a generalized force planning phase a statement of operational need is prepared. This statement does not yet identify the particular weapon but simply details the types of operations that it must be able to perform.

In the concept formulation stage, general characteristics of the weapon are specified. The major output of the concept formulation stage is a set of performance parameters, sometimes including availability specifications. These are input to the demonstration and validation stage where the major design concepts and considerations for the weapon are first specified in some detail.

The performance parameters that are the output of the concept formulation stage and the design concepts output from the demonstration and validation stage are then input into the full-scale development (FSD) phase where they are turned into a detailed design. During FSD, a complete design specification is produced that details how those performance parameters, or an updated set of them, are to be achieved.

At the start of the FSD phase the government picks a contractor and pays him to create a design from the performance requirements. Typically, the government signs off on that design at the end of FSD.

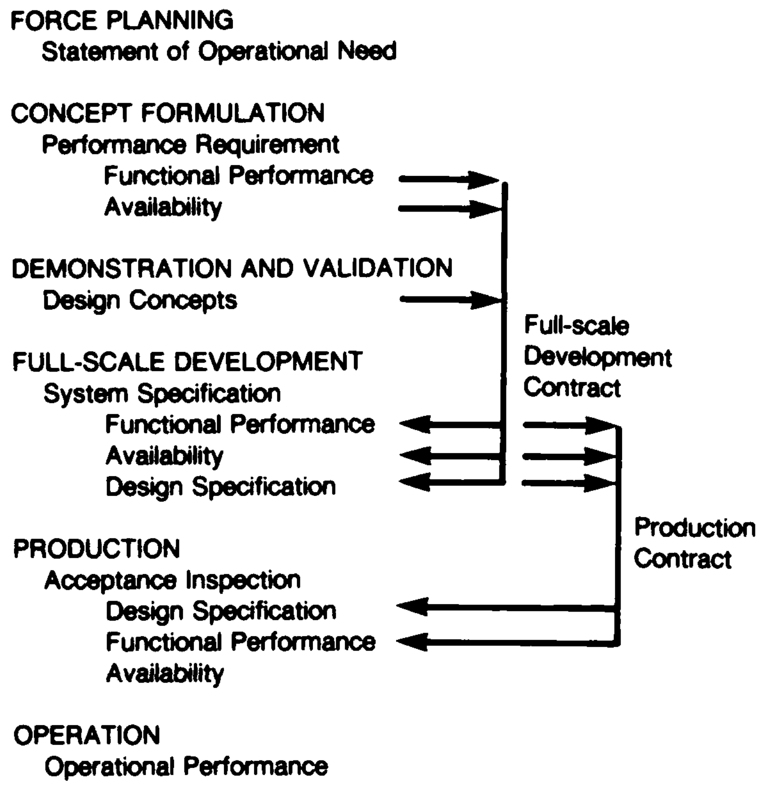

Fig. 8 -- Phases, documents, and contracts in a major military acquisition

After the design is approved, or sometimes before (depending on the rush to build and field the system), the production phase begins. In this phase the builder, who is usually but not always the same contractor who produced the design, receives the design specification and perhaps a reference to some performance parameters and then produces the weapons.

If we can speak of the production phase as ending, it ends with the products being accepted by the government. The builder produces the items and delivers them to the government. The government then tests the items to see if they are built to the design specification, and to see if they exhibit the required functional performance. Availability characteristics are also tested as completely as possible both in the laboratory and during initial field tests. But these characteristics typically require long and involved test periods; the testing environment at that time almost always differs from the actual environment the weapon will later be expected to operate in; and the weapon is typically operated and maintained by highly skilled engineers, technicians, and test pilots. Therefore, the acceptance tests, even coupled with the earlier development and production tests, seldom adequately predict the availability levels that the weapon will later display "when in ordinary use by the Service."

The final stage of the cycle is the operations phase. During this phase the weapon is used and misused, broken and fixed. For advanced, complex weapon systems, it is only during this phase that the true availability of the weapon is revealed.

The essence of warranties, especially performance warranties, is that they relate the actual operation of a product to some of the earlier specifications of how it should or must perform.

It is possible to overlay our warranty types on the earlier sketch of acquisition phases and documents, as shown in Fig. 9. At least to some extent, the specification warranties extend the contractor's obligation to adhere to the design and manufacturing specifications included in the production contract. Although part of nis compliance can be verified during the acceptance inspections, the warranties in effect extend the test period into the operations phase of the acquisition cycle.

Performance warranties extend the test period into the operation phase more forcefully. They compare the operation of a fielded system with some earlier specification of required performance. And, we have argued, because most of the functional performance requirements can be verified during acceptance testing, performance warranties should focus on availability.

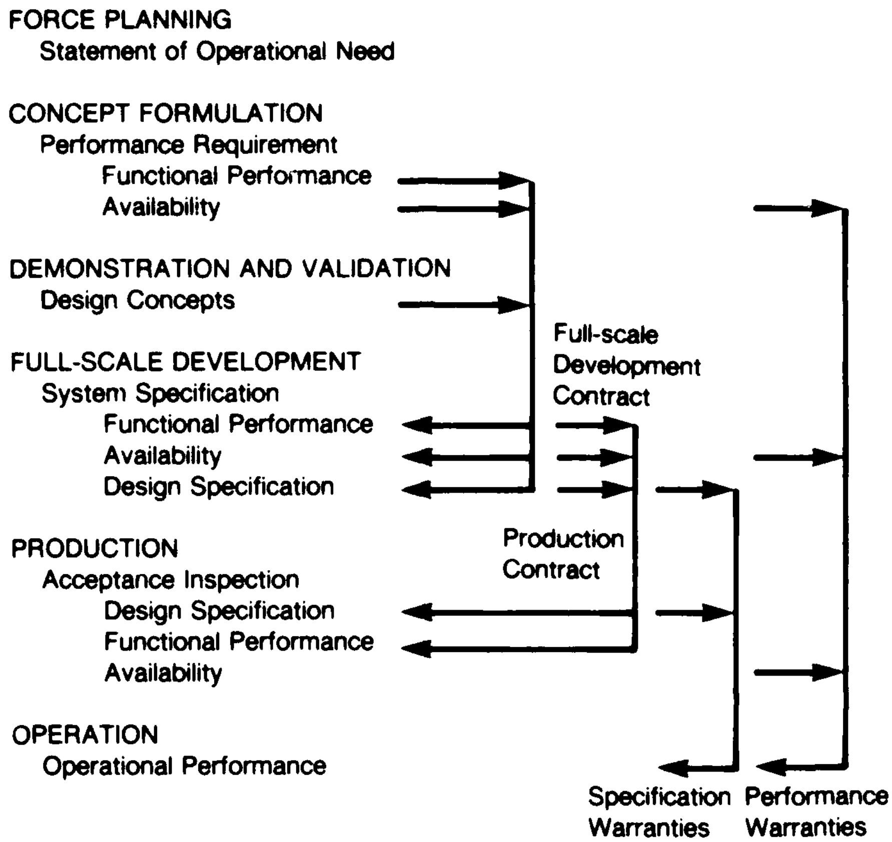

Fig. 9 -- The place of warranties in the acquisition process

Performance warranties can considerably alter the traditional acquisition process: No longer does government acceptance of the product relieve the seller of (all) responsibility for its subsequent performance in the field.[2] This opens up opportunities for the

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[2]Except, of course, for failures due to latent defects in materials and workmanship.

government to provide incentives for the seller to deliver a better product, but it also provides some new uncertainties and risks for both the seller and the government.

In particular, the performance warranty now seems to hold precedence over both design approval and product acceptance. This can have profound implications in cases where the producer is not the designer, where the Service has insisted on beginning production before FSD is completed, or in any case where the design is later found to be inadequate.

In fact, it is possible to argue that performance warranties provide what is sometimes called a "warranty of the design." To see this, let's examine two cases. First, when the performance warranty relates actual field performance to the performance parameters specified before the start of FSD, then it is fairly obvious that the seller is warranting the design as well as the performance. That is, the seller has signed up to provide the specified performance regardless of whether the governmental buyer has formally approved the intervening design, although there are some legal points here that may need to be settled in the courts. Such a shift of design responsibility to the seller raises important conflicts with the typical government practice of closely controlling the design and the product configuration.

The second case may not be as obvious, but if the performance warranty relates actual field performance only to the performance specifications in the *production* contract, we believe it still covers the design. For example, suppose that a particular contract contains both a manufacturing warranty (that the product will be built to the design specification) and a performance warranty (that it will meet the performance requirements). And suppose that the product turns out to be built to the design specification, but that it does not "work" satisfactorily. Then, unless the specification warranty somehow makes the performance warranty useless, the government still should have a valid case that the contractor needs to do something more to improve the product, or that he should pay a penalty.[3]

[3]This implicit warranty of the design should not be confused with the warranty of design and manufacturing mandated by the 1985 law. That warranty, which says that "the item provided under the contract will conform to the design and manufacturing requirements specifically

These considerations suggest that there are situations in which performance warranties *per se* may not be appropriate. There may be cases (second sourcing is an obvious example) where the government's need to be responsible for the design exceeds the likely benefits of any performance warranty.

Even in the extreme situation of a second-source contractor producing an item that has not yet been fielded (and proven) by the primary producer, however, there may be some cases where a limited performance warranty can provide incentives for the second producer to attempt to validate and improve the design rather than blindly building to the specification.

THE TIMING OF WARRANTIES

The third step in our conceptual framework for classifying and understanding warranties is the explicit timing aspect. So far we have talked about how military performance warranties relate operational performance to some earlier specification of that performance, but we have said nothing explicitly about when any of those warranties might be conceived, negotiated, or signed. Nor have we discussed what effect that timing might have on the opportunities and incentives that the contractor has for improving availability or for reducing system life-cycle costs.

We should like to make two points in regard to timing. First, there are three times when warranties can be introduced in a weapons contract: before development, before production, and after production (that is, any time during the operational phase of the system). Second,

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delineated in the production contract (or in any amendment to that contract)" appears to be purely a specification warranty [8].

The 1984 law, however, required a warranty "that the system and each component thereof were designed and manufactured so as to conform to the Government's performance requirements as specifically delineated" [9]. This clearly required the contractor to stand behind the design, until it was superseded by the 1985 law.

The rewording of the 1985 law removed the direct requirement for the production contractor to stand behind the design. We believe, however, that the requirement remains implicit in many applications of the performance warranty and that, because of this, each application of that warranty needs to be very carefully appraised and evaluated.

differing opportunities are available for improving the product during the different phases of the project.

FSD is certainly the best time for incorporating availability objectives into the design of the weapon; it is also the best time for developing adequate quality control concepts and procedures and proper support concepts and procedures.

During production, the choices are more limited because the design and most of the manufacturing procedures have been set. But they can still be changed, at least incrementally, if the contractor has an incentive to do so. And he still has direct, continuing control of quality assurance.

After production, the choices are still more limited: However, if the contractor is still involved, he can have some control over maintenance and support. He can even retrofit items in the field if that is appropriate under the terms of the warranty.

INCENTIVES AND REMEDIES

The fourth aspect of warranties concerns the incentives that are used by the government to induce the seller to achieve the objectives of a warranty. Such incentives are a crucial part of the warranty and should complement whatever incentives are contained in the weapon's basic production contract.

Price-Based Incentives

All acquisition programs contain incentives for the seller to live up to his production contract; the major ones being, of course, the threat that the government will refuse delivery, withhold payments, or perhaps even sue for noncompliance and damages and never deal with this seller again. When major weapons are being purchased, however, this take-it-or-leave-it firm-fixed-price paradigm often is not appropriate. The Service needs the item now, even if it is not quite up to specifications; the contractor needs his money to continue production and redesign; and both parties know that their only chance for getting a quality product is to continue to work together as well as they can.

Because of these conditions, the government often includes specific monetary incentives for achieving performance, cost, or schedule objectives. These incentives signal the contractor about which particular aspects of the program the government values most, and they provide prespecified bonuses or penalties for outcomes that, for whatever reason, differ slightly from those primarily specified. This latter attribute gives both parties some leeway in dealing with unexpected problems or opportunities.

Warranty clauses augment the basic contract. They identify special aspects of the program that the government wishes to emphasize--the "essential" aspects of availability in the field--and they provide incentives and options to the contractor.

A warranty is valuable to the buyer only to the extent that the seller lives up to his promises. The major incentives promoting this are, again, the threats that the government will withhold payments, sue for noncompliance and damages, and never deal with this seller again. But still, redresses of that type are drastic and quite unattractive to both the seller and the buyer.

Consequently, almost all warranties detail alternative incentives, either direct price incentives that affect the seller's revenue or task incentives that affect his costs. Price-based incentives for warranties are simply "performance incentives" under different names--they make the contractor accountable for the field performance of his product by basing his profits on that performance. Price- or revenue-based incentives are the most direct, easy-to-communicate types of warranties.

Cost-Based Remedies

Task or cost-based incentives are typically called remedies: prespecified tasks that the contractor must perform if his product does not deliver its warranted performance. Specifying remedies is quite different from specifying price incentives. There the problem consists of identifying critical performance attributes and specifying meaningful and unambiguous measures; here the problems are concerned with the allocation of tasks and costs.

Remedies (and all other incentives) differ from goals. The goal of a weapon's warranty is to increase the probability of the weapon's performing successfully under field conditions. The common remedies include the requirements that the seller repair failed items; provide additional numbers of the weapons (or components); or improve his design, manufacturing, or quality-control methods. The more these tasks increase the seller's costs, the more they reduce his profits. The incentive is thus for the seller to design the weapon initially so that it will perform adequately and to build it that way, thus incurring none of the extra costs. If, however, that proves impossible or much too costly, then the remedy provides the seller (and the buyer) with an option other than forfeiture or litigation.

Stated another way, properly specified remedies should encourage the seller to deliver a weapon that performs adequately sooner rather than later. The more specifically the warranty defines the remedies the contractor must perform, the easier it is to enforce and the easier it is to price and negotiate.

Figure 10 illustrates some of the major tasks that the contractor may be called upon to perform under a warranty clause after the acquisition has reached its operational phase. Most warranties will, of course, be written before FSD, or at least before production, and the contractor will have been expected to expand his reliability and maintainability staff, to design-in durability and supportability, and to accomplish many other tasks before the weapon is delivered to the user. So in Fig. 10 we are just looking at a small sample of his possible responsibilities. And, of course, these remedies differ both with and within the different types of warranties.

For example, under the simplest form of warranty--the bonus/penalty type--the essential performance requirements of the contract are tested, and, if they are met, the contractor may receive a bonus; but in any case, he incurs no further costs. If those essential performance requirements are not met, however, the contractor must pay a penalty, give extra spares to the Service at no additional cost, or do something similar.[4]

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[4]If the essential performance requirements are achieved, then the contractor need do nothing *more* under this warranty. This is because he

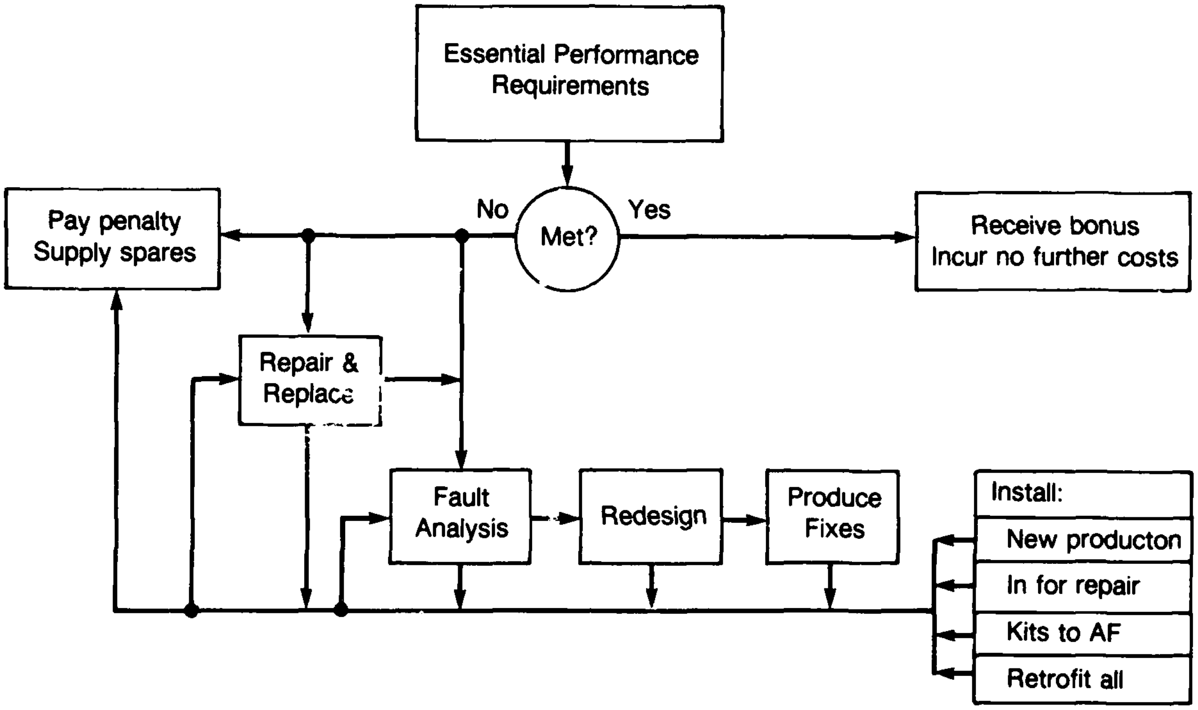

Fig. 10 -- Remedies performed by the contractor

Under the other types of warranties the remedies are more involved, often comprising combinations of the items listed in Fig. 10 and sometimes including all of them. The redesign warranty is often written to be the most inclusive. Under this warranty, if the essential performance requirements are not met, the contractor is responsible for redesign and perhaps retrofit to improve the items until they do come up to the required standards. But there can be many options to his continuing requirements: He may need to implement the redesign only in newly produced items, he may be required to retrofit it into all items that enter his shop for checkout or repair, or he may be required to retrofit the improvement to all items that have ever been produced. These differing work requirements will imply quite different financial requirements for the contractor.

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has already done his job during FSD by designing-in the specified availability and planning ways to achieve quality control and reduce support requirements, and during production by stressing quality control and proper techniques and materials.

THE WARRANTY MATRIX

We combine the timing considerations with the major types of warranties to produce the matrix we are using to classify warranties. This is illustrated in Table 1.

This matrix is labeled "appropriate" because it is intended ultimately to be prescriptive. However, we are not yet prepared to fill in the entries. We need to know more about warranties in general, and we need to know more about particular acquisition programs. For example, this table may have radically different entries for a high-risk program than for a low-risk one, different entries for an airplane than for a missile, etc.

We envision two generic types of entries for the table: (1) a simple indication of whether *any* military warranty is appropriate for a particular cell and (2) some indication of the remedies that the contractor could be forced to perform if the warrantied objective is not achieved. As an example of the first type, we believe that the cells under the functional performance warranty should normally remain empty or otherwise indicate that no such warranty is appropriate; and it is entirely possible that future research will indicate that certain forms of specification warranty should not be used.

Table 1

APPROPRIATE TYPES, TIMING, AND REMEDIES OF WARRANTIES

	Type of Warranty		
		Performance	
Timing in the Acquisition Cycle	Specification	Functional	Availability
Before FSD			
Before Production		Appropriateness and Type of Incentive or Remedy	
After Production			

The second type of entry envisioned for this table indicates the incentive or remedy called for by the warranty. As we shall see in the next section, many of the older warranties called for the contractor to perform depot-level maintenance for his weapons, and some called for him to redesign the weapon if it failed to achieve certain specified performance parameters; many contained a pricing schedule dependent on performance. These schedules, remedies, and tasks profoundly affect the relationship between the government and the seller, the incentives provided to the seller, the potential liability he is exposed to, and the price the government should expect to pay for the coverage.

IV. SURVEY OF SELECTED PRE-1984 WARRANTIES

During the 1970s and early 1980s the Services experimented with warranties. These early applications of warranties were mostly individual experiments: Each was instituted, often by a single influential official, as a special tactic applied to solve a particular problem; they displayed no common framework, objectives, or design.

Table 2 presents information on some of the more publicized early warranties and illustrates their diversity.[1] Short descriptions of these programs and warranties can be found in Appendix B. Table 2 illustrates diversity both along the vertical dimension dealing with the timing of the warranties (some of the early warranties were signed before FSD, others were signed as part of the production contract, and at least two well-publicized warranties were not conceived of until after the units were in the field), and along the horizontal dimension, dealing with the different types of warranties.

These older programs contained both specification warranties and performance warranties. Three distinct types of performance warranties were found: some with availability as their objective, some focusing on reliability, and some focusing on maintainability. The specification warranties, where they occurred in this sample of programs, all appeared in conjunction with a maintainability warranty and may have been a simple attempt to extend that warranty to include all possible types of "failures."

The names applied to performance warranties have differed from time to time and from one application to another. As mentioned above, we find most of the commonly used names less than helpful because regardless of how relevant those names may have been (or may not have been) 15 years ago, many of the more recent warranty applications employ more than one "type" or utilize aspects of several types. Consequently, our tables attempt to directly indicate the major aspects of the warranties, their objectives, incentives, and remedies.

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[1]This section draws on interviews with contractor and Service personnel, individual warranty documents, and published summary reports [7, 10, 11, 12, 13, 14].

Table 2

CHARACTERISTICS OF SELECTED PRE-1984 WARRANTIES

Timing and Systems	Specification	Availability (Performance)	Reliability (Performance)	Maintainability (Performance)
Signed before FSD				
C-17 (air vehicle)	F	E,$	E,$	E,$
DSCS-II, -III (COMSATS)			$	
Avionics				
F-16 (7 LRUs)				D
F-16 (2 LRUs)			E,S	D
Engines				
F109 (T-46A)	F			D
Signed before production				
Avionics				
ARN-118 TACAN	F		E	D
LN-35 INE (ALCM)	F	E	E	D
LN-39 INU (A-10)	F		S	D
APG-68 radar (F-16)			$	
Engines				
TF34 (A-10)	F			D
F100 (F-15, F-16)	F			D
F108 (KC-135)	F		$	D
F110/F220 (AFE)	F		$	D
Signed after production				
AN/ASN-92 INS (USN A/C)				D
APN-227 radar (P-3C)				D

D The contractor performs depot maintenance and usually incurs some penalty (money or the provision of spares) if turnaround time targets are not achieved.

E Engineering redesign (often including reproduction, reinstallation, and the provision of interim spares) is required if targeted performance is not achieved.

F Specification warranty; always accompanied by a maintainability warranty and apparently relies on the same incentives and remedies.

S Spares must be provided if required performance is not achieved.

$ A pricing schedule (bonus or penalty) dependent on performance.

We have adopted the names that have been the most helpful to us in differentiating among the several warranties and in highlighting the differing opportunities they provide for improving the outcomes of military acquisition programs. However, most maintainability warranties also are designed, at least to some extent, to promote reliability; and both maintainability and reliability warranties promote availability (because they represent its principal components), so these names should not be taken too seriously or applied too rigorously. We will discuss the performance warranties in reverse order.

MAINTAINABILITY WARRANTIES

Common objectives of maintainability warranties include controlling or improving built-in test failures, depot turnaround times, or general support costs. If these objectives are not met the contractor commonly provides additional spares (as a second best attempt to meet the objective) or pays a monetary penalty (indicating his failure to meet the performance objective).

The most familiar form of maintainability warranty is an RIW, which calls for the contractor to perform the depot repair function for failed items over a specified period of time for a fixed cost. This type of warranty may call for the repair of all failures, it may call for the repair of all failures after a certain number of basic allowables (the target break-rate or "threshold"), or it may specify some other triggering device. In all cases, however, the fixed price of the warranty insures that the contractor's profits decrease each time he performs a repair action, thus inducing him to meet the specified objective, initially if that is feasible or as soon as possible if unexpected problems appear. The fixed price also fixes in advance the government's depot repair costs for the period of the warranty.

The RIW is the simplest and the most common form of military warranty and is similar to the warranty that consumers typically get when they buy a new refrigerator or a new car. A warranty like this helps the user to fix his repair costs, and it may lower those costs if the contractor is better at fixing things than the owner. But an RIW does not insure against getting a lemon: The warranty says only that the seller will fix certain things that break; it doesn't say anything about the car or the weapon not breaking, and it doesn't say anything about what kind of condition the car or the weapon will be in after the warranty is over.

Sometimes an RIW is incorporated with a reliability warranty or even an availability warranty; but, as Table 2 indicates, often it is the only type of performance warranty issued for a weapon. In the latter case it operates substantially as a fixed-price contract for initial contractor support giving the Service the benefits of the contractor's familiarity with the characteristics and requirements of the new weapon and providing additional (and better trained) support personnel to deal with initial support problems.

Most of the maintainability types of warranties indicated in Table 2 are simple RIWs calling for the contractor to perform the depot repair function for all failed items and calling for penalty spares if a turnaround time target is not achieved. The major exception is the warranty on the C-17 air vehicle.[2] This warranty calls for the field measurement of some five maintainability parameters, redesign and retrofit of problem subsystems if required levels of maintainability are not met, and the provision of a bonus if they are exceeded.[3]

RELIABILITY WARRANTIES

In a reliability type of warranty the contractor promises that his weapon will exhibit specified levels of field-measured reliability--mean-time-between-failure, mean-time-between-removals, etc. If that reliability is not achieved the contractor must undertake a specified remedy, such as returning money to the government, supplying additional spares, or redesigning the system.

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[2]The C-17 warranty falls into this category of "early" warranties only because it was signed as part of the C-17 air vehicle development contract in 1981. Its performance parameters will not be tested until sometime in the 1990s.

[3]The maintainability parameters specified for the C-17 warranty are the air vehicle quick turnaround time, air vehicle maintenance manhours per flying hour, air vehicle mean-manhours-to-repair, and three measures of the adequacy of built-in test: fault detection percentage, fault isolation percentage, and false fault indication percentage.

One special characteristic of this type of warranty is that the promised actions may be repetitive: The contractor may be required to test his weapon and, if it does not measure up, to redesign and retrofit it, then to test it again and perhaps redesign it again, etc. This can expose the contractor to large potential liabilities.

Table 2 shows that our sample of older warranties contains reliability warranties of three different types: warranties calling for engineering fault analysis, repair, and retrofit if the specified reliability requirement is not met (these are designated with an "E"); warranties simply calling for a dollar bonus or penalty if the goal is exceeded or not attained ($); and warranties calling for a penalty-in-kind, such as extra weapons or component spare parts when its reliability targets are not met (S).

The S type of reliability warranty is found in our sample only on the LN-39 inertial navigation unit used in the A-10 (and a few F-16) aircraft and on the two F-16 avionics line-replacable units (LRUs) with MTBF guarantees. The $ type of bonus or penalty warranty is found in two guises: as a stand-alone warranty on the two most recent generations of the Defense Satellite Communications System satellites and on the follow-on (APG-68) radar for the F-16; and as a supplement to maintainability warranties on several of the engine contracts.[4] E types of reliability warranties appear for several of the avionics systems and for the C-17 air vehicle.

The C-17 again has the most interesting combination of warranties. Objectives, in the form of both requirements and goals, are specified for five different reliability parameters.[5] If the requirements are not met the E-type warranty is invoked; if they are exceeded the $ bonus is paid.

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[4]Performance incentives have not commonly been called warranties, but they certainly fall under the definitions: They depend on use in the field; and they contain remedies, in this case bonuses and penalties, that depend on that performance.

[5]The reliability measures for the C-17 air vehicle are air vehicle mission completion success probability, air vehicle analytic mission reliability, air vehicle mean-time-between-removal, and two measures of air vehicle mean-time-between-maintenance: corrective maintenance and on-equipment inherent malfunction only.

AVAILABILITY WARRANTIES

Availability is some complex combination of reliability, maintainability, spares, and other support elements. Thus, all of the maintainability and reliability warranties contribute to some greater or lesser extent to availability.

Direct availability specifications are found on only two of the warranties in our sample: the C-17 and the inertial navigation elements (INE) of the air launched cruise missile. The INE warranty calls for a certain percentage of ground tests and test flights to be successful, or engineering fault analysis, redesign, and retrofit actions must be taken. The C-17 warranty again contains requirements with bonus possibilities.[6]

OBSERVATIONS ON THE PRE-1984 WARRANTIES

Table 2 indicates that basically three types of performance warranties were written before 1984: maintainability, reliability, and availability. Further, the entries in the table suggest that three basic types of incentives and remedies were commonly called into action when the performance objective was not achieved: monetary incentives (penalties and bonuses), service remedies (repair or replacement), and engineering and manufacturing remedies (redesign and retrofit).

A surprising number of the programs in Table 2 included several of these different warranties, incentives, and remedies. And at least two, the C-17 and the INE for the air launched cruise missile included at least one entry in every column. Each warranty and each remedy can involve a considerable liability for the contractor and a high price for the government. In most programs the potential (but of course not the expected) liability was much larger than any potential reward.

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[6]The availability warranty parameters for the C-17 are the air vehicle full mission capable rate, partial mission capable rate, and maintenance downtime per sortie.

Were These Warranties Worthwhile?

Many of the warranties implemented in the 1970s are now completed and some have been evaluated. Often the initial evaluations of the warranties were made by program, contracting, or contractor officials with possible biases, and we cannot at this time vouch for any of their findings. The following paragraphs present what seems to be the current consensus.

At least five or six of the older warranties were deemed successful in some manner or other. These include the warranties on the DSCS satellites, the Carousel INS, the LN-35 INE, the LN-39 INU, the AN/ASN-92 INS, and the APN-227 radar. Other warranties were associated with successful programs, but the contribution of the warranties is unclear. Most of the engine warranties fall into this category. Engine acquisitions typically include continuing involvement by the contractor in large and costly component improvement programs that blur the contribution of the warranties.

Several of the other warranty programs experienced definable problems; the remaining ones are too new to be evaluated. The F-16 avionics warranty included de facto disincentives for improvement ECPs, and some sections of the warranty underwent litigation. Additional problems with contractor/government interactions hindered the performance of the ARN-118 TACAN warranty. We have no information on the current status of the APG-68 radar warranty. And the C-17 and F109 programs have only begun. Additional details on all of these pre-1984 warranties can be found in Appendix B.

As mentioned above, we cannot vouch for any of the current evaluations and will later suggest that all of the early warranty programs should be reexamined in detail. We also question the current practice of evaluating warranties in isolation. A warranty represents only one, often small, part of any acquisition program; and although we believe a good warranty can contribute to the success of a good program and a poor warranty may be able to cripple an otherwise viable program, we also believe that the warranty will seldom be the main cause of program success or failure.

Nevertheless, these older warranties represent a substantial amount of experience and should be providing guidance to those who are now trying to cope with warranties on newer systems. These older warranties need to be examined more closely, carefully evaluated individually, and then compared, using consistent criteria, before experience with them is lost.

We were able to make a pass through the available data and to talk with some of the program offices and some of the contractors, drawing some initial conclusions, or at least hypotheses, about the attributes that separate more and less successful warranties. But much more detailed work needs to be done before anyone can confidently declare that warranties for weapons are, or are not, worthwhile.

Positive Aspects

Our analysis of the available data, reading of program documents, and discussions with both government and industry officials suggest to us that at least four factors may be important influences on warranty outcomes:

- Specific, measurable objectives
- Explicit, unambiguous remedies
- Explicit duties for the government
- Reasonable prices and expectations

At this time we cannot say that these factors insure favorable outcomes, but it appears that they are important, that they are often associated with better programs, and that their absence is frequently mentioned as a problem on the more troublesome programs.

One Worrisome Aspect

Most of the maintainability warranties were written to require depot repair and perhaps other support activities for the warrantied items, which were usually avionics LRUs. These warranties are usually seen as procedures for inducing the contractor to improve reliability as well as maintainability because the more often the item fails the more often the contractor must fix it, hence the more resources he must devote to repair. If he simply makes it more reliable to start with or if he improves the design later on, so the argument goes, he will save money on repairs; so if the design or redesign activities are predicted to be less costly, the contractor should concentrate more on improving reliability than on performing maintenance. And this gain in reliability is what the Service really values.

This argument is fine as far as it goes, but it fails to recognize that many of the warranties are written in ways that virtually assure reliability-improving "no cost" ECPs will seldom be cost effective for the contractor. Often many additional tasks are delineated that neatly tie up the contractor's responsibilities, at least from the government's point of view. But those tasks often involve large and uncertain liabilities for the contractor, liabilities that he is understandably reluctant to assume when his option is simply to continue to repair individual failed items.

For example, part 1.2 of the warranty on the LN-39 INU warranty for the A-10 aircraft states that:

> Under the RIW defined herein, the contractor will be required to correct or replace at his option at no additional cost to the Government, any INU which fails during the warranty period. Maximum latitude shall be given to the contractor to make no-cost changes to improve R&M, however, the Government reserves the right to approve all Class I Engineering Change Proposals.

However, if the contractor chooses to implement a "no cost" ECP he must also incur:

> 3.2.d The cost of preparing RIW ECPs, and of incorporating RIW changes into all warranted INUs, Operational Flight Program software, including changes in technical data, spare or repair parts, support equipment (SE) and SE software, and any other data or supplies procured under this contract necessitated by incorporation of these ECPs, shall be borne by the contractor at no additional cost to the government.

3.2.e All returned INUs shall be updated to the latest approved configuration in accordance with implementation schedules contained in ECPs.

3.2.f The contractor may, if approved in the implementing ECP, institute field changes to effect modifications.

3.2.g Within sixty (60) days after the conclusion of the warranty period, the contractor shall, at no additional cost, provide necessary modification kits and Data to permit the Government to modify all INUs which have not been updated to the latest approved configuration.

Another aspect of this problem was evident in the F-16 LRU warranties where the Air Force contracted with subcontractors (suppliers) for warranties. Those firms apparently proposed a number of ECPs after their LRUs experienced high failure rates, but the prime, integrating contractor had the power to disapprove or at least discourage configuration changes, and probably did so because the ECPs would have increased *his* costs even though they may have substantially lowered total system-wide (Air Force, prime contractor, and subcontractor) costs [10]. We repeat our earlier warning: Giving contractors greater incentive by transferring costs is difficult and clumsy, especially in acquisitions involving more than a nominal amount of uncertainty.

V. FIRST LOOK AT SELECTED 1985 LAW WARRANTIES

The warranties discussed in the last section are interesting historically and we hope they will eventually provide clues for improving future warranties. But it is the newer warranties that are being written today under the requirements of the 1985 law that are the real interest of this study and whose structure and implementation we ultimately hope to influence.

Table 3 contains information on a small sample of warranties for weapons written since January 1, 1985.[1] Appendix C contains short descriptions of these programs and warranties. We expected that the recent warranties should be more uniform than the earlier ones because they are all based on the 1985 law and all of them apparently comply with that law. We find, however, that even within that constraint there is a lot of leeway on how the warranties can be structured and implemented.[2]

ATTRIBUTES OF THE PROGRAMS

Before attempting to compare these more recent warranties with earlier ones, we note some differences between the samples. One major difference between the programs summarized in Table 3 and those discussed in Table 2 is that these newer programs are nearly all in some aspect of the production phase of their procurement. A half dozen of the earlier programs had warranties applied while they were still in development, and two had warranties applied after they were out in the

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[1]We appreciate the assistance of personnel at Headquarters Air Force Systems Command in assembling the warranty clauses on these weapon systems.

[2]Alan Yuspeh, the General Counsel of the Senate Committee on the Armed Services, remarked in a speech in St. Louis on October 23, 1985, that his committee had asked the Government Accounting Office (GAO) to look at how the Services were complying with the warranty laws. He said that GAO reported all three Services seemed to be conforming with the law, but that the law was so vague that almost anything the Services did could be argued to conform.

Table 3

CHARACTERISTICS OF SELECTED 1985 LAW WARRANTIES

Timing and System	Type of Warranty				
		Performance			
	Specification	Availability	Reliability	Maintainability	Functionality
Signed before FSD					
SINCGARS airborne radio	F		E	D	
Initial Production					
F100 engine (F-15/F-16)	F		$	D	
Avionics & electronics					
NAVSTAR user equipment	F			D	
STD PA INU	F		E	D	
STD and F-15 RLG INU	F		E	D,E	
SCPS-2 protection system	F	?	?	?	?
SCDAC air data computer	F	?	?	?	?
MX Peacekeeper ICBM					
Support equipment	F			D	
Ops support equipment	F			D	
Follow-on Production					
F-15 (1985 buy)	F	?	?	?	?
TR-1/U-2R aircraft	F	?	?	?	?
AGM-65D Maverick missile	F	?	?		
MHU 196	F	?	?	?	?
EWWS update	F	?	?	?	?
MX Peacekeeper ICBM					
Third-generation gyro	F		D		D
Stage I and FTOS	F	E		D	
Stage III	F	E,D			
Ordnance initiation system	F			D	

D The contractor performs depot maintenance and usually incurs some penalty (money or the provision of spares) if turnaround time targets are not achieved.

E Engineering redesign (often including reproduction, reinstallation, and the provision of interim spares) is required if targeted performance is not achieved.

F Specification warranty (now required by law).

$ A bonus or penalty, dependent on performance.

field. The 1985 law warranties, however, nearly all apply to production contracts because that is what the law now covers and because few new programs have entered FSD since that law came into effect.

The programs in the two samples also differ somewhat in type. The sample of programs in Table 3 contains air vehicles, avionics systems and LRUs, and aircraft engines just as the sample in Table 2 did; but it contains far fewer engine warranties and adds some ten warranties on different aspects of the MX "Peacekeeper" ICBM.[3] So, generally, we need to be somewhat careful in comparing the two samples.

Most of the engines listed in Table 2 will eventually also appear in Table 3. Engines and many other military items are procured in annual lots, and eventually a new contract will be signed for (several years' buys of) many of the older engines. Recent experience indicates that the warranty on the current buy of a particular engine is usually similar to, but slightly longer than, the warranty on, say, the 1984 buy or the 1983 buy.

The MX warranties seem to have been created from scratch during 1984 and grafted onto existing production contracts. They have been continued almost without change on these 1985 contracts. The MX warranties mostly involve repair or replace, limit the contractor's liability to fairly low levels, and cost the government little. However, the warranties on the solid rocket boosters for each of the three stages of the missile generally involve redesign actions because those items are seldom susceptible to repair if they fail. They also contain limited liabilities and modest prices.

ATTRIBUTES OF THE WARRANTIES

Tables 2 and 3 are quite similar, in structure, but there are three major differences: The specification column of Table 3 contains an entry for every program, the remedy entries contain "?"s for a number of programs, and a new column indicates the presence of warranties for functional performance (it includes several "?"s also). We discuss these topics in reverse order.

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[3]More than the ten warranties are actually represented here as many of these components come from dual sources.

Functional Performance

Table 3 contains a column pertaining to functional performance. The contract for the third-generation gyroscope, a component of the Peacekeeper ICBM, contains direct references to "specifications and acceptance test procedures" that must be met or the items will be repaired at the contractor's expense. The performance warranty for the 1985 buy of the F-15 aircraft states that the "specified performance requirements are those delineated in the Statement of Work as relating to the Part I specification."[4] The TR-1/U-2R performance warranty states that "the specified performance requirements are those delineated in SECTION C of this contract. Specifically, paragraph 3.1.2.1. Aircraft Performance of Document SP4762;"[5] and the SCPS-2 warranty defines the performance requirements as "the demonstration/test requirements delineated in Table 3 of Specification 412A-07878-21025."[6]

All of those specifications sound to us as if they cover functional performance as well as availability. It also seems that they are failing to pick out particular "essential performance requirements," preferring to cite entire pages or sections of documents. However, only detailed discussions with the contractors and the program office personnel will allow intelligent documentation and evaluation of these potential criticisms.

The context in each of these cases strongly suggests that the specifications mentioned are functional specifications, so we have placed an entry in the functionality column for these and several other programs. But note that we have used two types of entries: a "D" and a "?". The "D" again indicates that the warranty calls for the contractor to perform depot-level maintenance on failed items. The "?" indicates that the warranty does not explicitly indicate just what remedies may be called for.

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[4]Contract F33657-85-C-2086, p. 69.
[5]Contract F33657-84-C-0181, p. 21G.
[6]Contract F33657-85-C-0079, p. 41.

Availability, Reliability, and Maintainability Warranties

We have also had to use "?"s under many of the availability, reliability, and maintainability warranties. We will comment at length on those "?"s in a moment, but first let's look at the half-dozen or so of the warranties under those columns in Table 3 that contain no "?"s. For these programs the objectives and remedies are spelled out in the warranty in some level of detail, and for the majority of these programs the warranties are somewhat similar to the earlier ones that were listed in Table 2.

The maintainability warranty is again the most common type of performance warranty. It is present for every program except for the missile programs where operations, and to some extent testing, typically destroy the items, and for several of the missile gyro and fusing assemblies, which are expected to operate continuously.

Several of the reliability warranties again call for engineering analysis, redesign, and retrofit; and at least one calls for bonus and penalty payments. But note here that again some of the missile components have slightly different warranties--several of the electronics reliability warranties calling only for repair activities. Finally, there are again a few availability warranties, here dealing with the stages of the MX. These warranties are based mostly on test firings of randomly selected missiles; if the missile malfunctions the contractor must perform engineering fault analysis and perhaps redesign and retrofit.

A New Trend in Specifying Remedies?

In the older warranties discussed in Sec. III the remedies were always written out in great detail. This useful procedure allowed both the contractor and the government to know what to expect if the objectives were not initially achieved. A number of the newer warranties listed in Table 3, however, do not follow that procedure.

For example, page 70 of the warranty for the 1985 buy of the F-16 fighter simply states under "contractor's responsibilities" that:

(4) Upon timely notification of the existence of a defect, in accepted supplies or services, the Contractor shall submit to the Contractor Officer written recommendations for corrective actions with supporting data within ninety (90) days. The Government will issue direction to Contractor within ninety (90) days whether to correct, partially correct, or not to correct the alleged defect.

This could include redesign, reproduction, and the complete retrofit of all delivered aircraft, or it could conceivably be limited to a simple repair or a small change in an operating manual. And in different situations each of these different "corrective actions" may be appropriate. Because we don't know what might be expected, we don't see how this warranty can be costed, priced, or negotiated.

Specification Warranties

Each program listed in Table 3 contains a specification warranty because these are now required by law. In fact, most of the programs use similar wording, each compelling the contractor to warrant that his weapon is free from all defects in material and workmanship and that it conforms to the design and manufacturing requirements specifically delineated in the production contract. We have placed an "F" in the specification column for each of these warranties, indicating that if the weapon is found to be not acceptable the contractor must either fix it or replace it. This is somewhat of a supposition on our part, however, as few of the warranties spell out remedies for failure of the specification warranty. This is possibly a holdover from the pre-warranty days when these clauses were typically included as part of the standard acceptance clauses of most acquisition contracts and the implicit threat was that the government would refuse to accept the item if it failed to conform.

VI. SUMMARY AND CONCLUSIONS

LESSONS FROM THE SERVICES' EXPERIENCE WITH WARRANTIES

In Sec. III we saw that there were basically three types of performance warranties written before 1984 (maintainability, reliability, and availability warranties), and that there were three basic actions invoked if the required performance was not achieved (bonus/penalty, repair/replacement, and redesign/retrofit).

Initial analysis of those early warranties suggested that at least four factors may contribute positively to warranty outcomes:

- Specific, easily measurable objectives;
- Simple, explicit contractor incentives and remedies;
- Simple, explicit government duties; and
- Reasonable prices and expectations.

Most of those warranties directly or indirectly aimed at improving the field reliability of the warranted items, and most intended to encourage the contractor to adopt "no cost" ECPs to improve the items if their initial performance was less than some targeted level. However, most of these warranties also prescribed so many additional "no cost" duties that had to be associated with the ECPs that it appears to us that it would seldom have been cost-effective for the contractors to propose such ECPs.

The 1985 Law Warranties

The current warranty law became effective on January 1, 1985, so it is too early for any direct evidence concerning the effectiveness of the warranties written under that law. We were able, however, to compare the characteristics of a set of newer warranties with the characteristics of our set of older ones and to make some indirect inferences.

Many of the characteristics of the warranties for the newer programs are similar to the warranties for the earlier programs: Most have maintainability warranties where the contractor performs interim depot support for a fixed price; a few have reliability and availability warranties, with perhaps half of those calling for fault analysis and redesign; and all of the programs (because of the current laws) contain some provision for specification warranties, but usually without specified remedies. However, we also find that the newer warranties differ in several ways from the older ones, ways that we believe may be important for the success of the newer contracts. Three aspects deserve particular mention: (1) the warranty of functional performance, (2) the nonspecificity of the objectives of the warranties, and (3) the nonspecificity of the remedies.

Warranties for Functional Performance. Although all of the older warranties were concerned with the availability, reliability, or maintainability of the warrantied weapons, many of the newer warranties seem to be just as concerned with functional performance.

Under the 1985 law a warranty is required on the *essential performance requirements* of each new major weapon system. We have argued that most elements of functional performance can be adequately tested before acceptance, and that availability is the area that most needs the help of warranty clauses. Many of the newer warranties do not seem to share this viewpoint, making no apparent distinction among the different kinds of performance covered in the warranty.

We suggest that in most cases the warranting of functional performance serves no useful purpose and probably works against the best interests of both the contractor and the government.

Specifying the Objectives of a Warranty. Many of the variables that must be considered in specifying a valuable and workable objective for a performance warranty are quite complex. What really is availability? And how should we measure it? Should we specify it at the system level, at the subsystem level, at the LRU level, or where? How do we specify or measure reliability? Or maintainability? These are very real questions that were generally dealt with specifically and in some detail in the early warranties, whereas they are treated only as generalities (if at all) in many of the more recent ones.

For example, consider the statement of coverage on the performance warranty of the 1985 buy of the F-15 ("specified performance requirements are those delineated in the Statement of Work as relating to the Part I specification") with the statements in, say, the early LN-39 INU warranty. There the warranty covers some 22 pages and was not considered unusually lengthy. Most of the 1985 law warranties that we have seen total between five and ten pages.

The older warranties stated explicit, measurable, "essential" objectives of their programs. That certainly provided guidance to the contractor and forced him to acknowledge the importance of availability, but it also raised the risk of directing too much attention to particular aspects of availability and diverting the contractor from more worthwhile but less "measurable" activities.

The less-specific wording of the newer warranties allows the government and the contractor much more leeway to attend to the attributes of performance that are troublesome *in the field*, and it does not attempt or need to specify easy-to-understand measures for complex phenomena and systems. But we are afraid that this approach provides too little guidance to the contractor, especially in the early stages of a program, and that it raises the risk of disagreements and even litigation when field performance begins to be evaluated.

Only time will tell if this new approach is workable in the context of major acquisition programs, but until that evidence becomes available we suspect that the nonspecific warranting of all performance, or even all availability, probably works against the best interests of both the contractor and the government. We suspect that the warranty should concentrate on a small number of essential and measurable objectives, or the warranty requirement should be waived.

Specifying the Remedies Expected of the Contractor. Specifying the tasks that the warranty contractor may be required to do under a warranty is just as important as specifying the performance objectives of the warranty. Under most of the earlier warranties and some of the newer ones, the tasks that the contractor is expected to perform if his warrantied objectives are not achieved in the field are well spelled out. However, we find that a considerable number of the newer warranties are not specific about those tasks: It is common to find warranties requiring only that the contractor take "corrective actions" that could include redesign, reproduction, and the complete retrofit of all delivered aircraft, or could conceivably be limited to a simple repair or a small change in an operating manual.

We suggest that detailing the tasks the warranty contractor may be required to do unde a warranty is an extremely important part of specifying a productive, workable warranty.

Many of the older warranties we examined emphasized the depot-repair function (interim contractor support), and by negotiating the full price in advance they often make it profitable for the contractor to undertake several of the other tasks, including limited redesign and retrofit, to improve performance and reduce the requirements for depot repair.

Some of the newer warranties emphasize the fault-analysis task. By leaving the repair and retrofit actions open to negotiation, the government may hope to promote fixes that improve fleetwide performance or cost effectiveness, rather than just prespecified fixes tied into the contractor's profit structure. It is not obvious, however, just what incentives this provides for the contractor. In some cases he may decide that it is not in his best interests to build in all the availability possible, but rather to wait until the items are in the field and then propose involved and expensive fixes, just the actions that warranties were designed to prevent.

Again, those newer warranties need to be tracked and evaluated over a number of years before we can make any final judgments; but until that evidence becomes available, we suggest that the more specific a warranty is concerning the tasks that the contractor will be expected to perform, the easier it will be to negotiate, price, and enforce it.

Some Implications of Ambiguous Warranty Specifications

Most of these implications have been alluded to above; here we will simply summarize them again.

- **Implications for Success**. Unless warranty objectives are specified simply, precisely, and in a measurable manner, it is not possible to determine if a warranty has helped to promote a successful procurement.
- **Implications for Pricing**. Unless the tasks the contractor is expected to be responsible for are specified precisely and exhaustively, it is not possible to estimate and negotiate a reasonable price for the warranty.
- **Implications for Computing Cost Effectiveness**. Unless both the objectives and the expected tasks are detailed, it is not possible for the government to estimate either the cost of the warranty or the full cost of any alternative strategies.
- **Implications for Constructing Liability Ceilings**. Again, unless we know the requirements and obligations of the contractor, it is not possible to specify liability limits that will promote compliance for a reasonable price on the one hand and insure against contractual default on the other.

SUGGESTIONS FOR FURTHER RESEARCH AND ANALYSIS

Our initial samples and evaluations of warranties from the 1970s and the 1980s indicates that valuable inferences can be drawn even from limited information. For warranties to be truly understood, however, and for estimates of their cost effectiveness to be computed, much more information must be accumulated, normalized, and analyzed.

Many of the warranties implemented in the 1970s are now completed and at least some of those programs were considered successes--at the very least they forced the contractor to direct more attention to availability than had previously been done. That warranty experience should be providing guidance to the people who are now trying to cope with warranties on newer systems. But it is our observation that much of the earlier experience is in danger of being lost. Our review indicates that although some evaluations of the older programs have been made, they have usually concentrated on single aspects of particular warranties. We found few studies that compared different warranties and fewer still that used consistent criteria.

We need more information concerning those earlier programs: information detailing program objectives, specific warranty objectives, contractual remedies and the evaluations that triggered them, prices and the actual costs that were incurred, and the portions of these that were borne by the contractor and the government. Much of this information may already have been lost, but we need to salvage as much of what remains as is possible, because that will be the only information base we have for specifying new warranties over the next several years.

At the same time, adequate records should be accumulated on the warranties that are currently being written, including warranties by all the Services. There is obviously much to be gained by the interchange of information on approaches as well as details.[1] Sporadic data and contractual language are currently being collected by agencies from the several Services, but this effort needs to be coordinated, consolidated, and formalized. The first requirement is obviously for high-level agreement on the types and quantities of information that are needed at the beginning of each program, and how that information will be updated and followed during the course of each program.

While data are being collected and coordinated, the Services need to develop appropriate methods for evaluating warranties and warrantied programs. This is an especially important and sensitive task. Each of the Services has some form of manual now, either published or in preparation; but unfortunately most do little more than compare interim contractor support with organic depot repair. Few recognize that risk and uncertainty are the major environmental and contractual factors affecting the desirability of warranties [1, 2, 3, 15].

[1]Some data are being collected at AFSC now and within the other Services as well. Most of the information reported in this Note came from the Product Performance Agreement Center (PPAC) and AFSC. But current information needs to be continually collected; and better, broader evaluations of both current and past warranties need to be conducted. The Air Force is preparing a directive to require each program office to send a copy of each warranty it writes to the PPAC. We hope that this is required for all the Services. But more information is needed concerning the objectives of the program, methods of measuring compliance, results of the cost-benefit evaluation, methods used in that evaluation, etc.

IMPROVED POLICY GUIDANCE THAT CAN BE ISSUED IMMEDIATELY

Our research to date yields five broad observations on warranties that we believe should be included in all new policy statements and documents. The first observation emphasizes objectives. The real promise of warranties is that they offer a method of providing incentives to the contractor to deliver and support a working weapons system. DoD and the Service Headquarters need to inform their project officers of the possibilities and options available for using performance warranties to increase the probability of achieving the weapon's availability goals.

Second, there is a real need for improved evaluation criteria and procedures--and this includes procedures for *a priori* cost-effectiveness estimates as well as *ex post* cost and benefit evaluations. So long as those procedures are limited to logistics or life-cycle costs, it is unlikely that any part of the project office, or the user or support communities, will be concerned with more important and more general benefits.

A third area of needed policy guidance deals with waivers, exclusions, and the tailoring of warranties. The 1985 law allows the Secretary of Defense to waive part or all of the warranties on a particular weapon; and it allows the Services to include reasonable exclusions, limitations, and time durations in their warranties. In practice we have had almost no waivers but have seen a large amount of uncoordinated tailoring of individual warranties, tailoring that has been at least tacitly approved by the higher authorities. DoD policy guidance is needed in both areas. DoD should provide guidance on when second-source producers and others should be exempt from performance, but not specification, warranties. And the DoD needs, in general, to specify which types of warranties may be waived in other situations, which may be tailored, and which are applicable as they stand to all acquisitions.

Fourth, policy guidance should deal with the timing of warranties. It should relate the objectives of the programs (and thus the warranties) to methods of achieving those objectives, and this deals with the opportunities and the incentives that are available during the different phases of the acquisition.

Finally, we need to explicitly address the concept of risk sharing. Warranties are only a contracting device. They cannot affect any of the real uncertainties and risks underlying the development and procurement of advanced weapon systems. The uncertainties are always going to be there, and when they are large, as they usually are in the procurement of major weapon systems, the government must continue to bear a substantial portion of the risk.

The appropriate role for warranties in military acquisition is to provide a structure for managing the inevitable technical uncertainties that continue after delivery and acceptance. If the objectives of the warranty and its pricing structure are simple and explicit, and if the responsibility and obligations for corrective action are reasonably apportioned between contractor and government, both parties should have an incentive to produce and field an effective and efficient weapons system.

Appendix A

SELECTING PREFERRED LEVELS OF FUNCTIONAL PERFORMANCE AND AVAILABILITY

The program office for the procurement of an advanced weapon system must perform three major sequential tasks: define the preferred levels of performance; contract for their development, production, and delivery; and verify that those have been achieved.

Figure A.1 illustrates in a very simple fashion the essentials of the first task. The vertical dimension represents a measure of functional performance for a hypothetical weapon; and the horizontal dimension represents some composite measure of its availability. Both types of performance contribute to the combat effectiveness of the weapon, and each type can be traded off to some extent against the other. For example, an attack aircraft needs both speed and

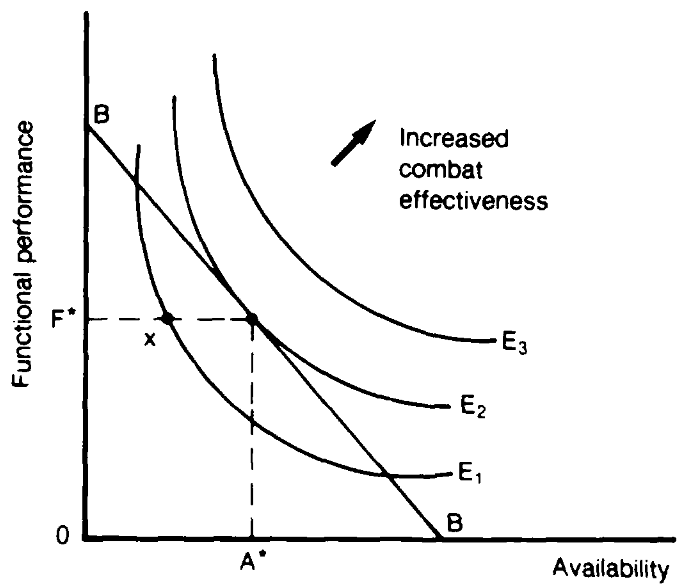

Fig. A.1 -- Tradeoffs between functional performance and availability in a hypothetical weapon availability to be effective, and the lack of speed on a particular type of aircraft can be offset at least somewhat by increased reliability or maintainability, which allow more planes to be in the air at any time. Similarly, to be effective, ICBMs must be both accurate and ready; one attribute without the other is worth little.

The smooth curves E_1, E_2, and E_3, in Fig. A.1 represent increasing levels of combat effectiveness and the different combinations of functional performance and availability that might contribute to each. The BB line is the budget constraint for the weapon; only combinations of functional performance (F) and availability (A) on or to the left of this line are affordable. The point at F^* and A^* then represents the highest level of combat effectiveness available within the budget.

This approach differs fundamentally from simply minimizing the life-cycle costs associated with a specified level of F. Our model assumes that both functional performance and availability contribute significantly to combat effectiveness. This can be represented algebraically as

$$\text{Max } \pounds = E(F,A) + \lambda[(C^o - C(F,A)]$$

where E(F,A) represents the combat-effectiveness function, C(F,A) represents the cost function, and C^o is the cost constraint or budget. £ is maximized at the values of F and A where the marginal contribution of each to combat effectiveness represents the same proportion of its marginal cost. That is,

$$\lambda C_f = E_f$$
$$\lambda C_a = E_a,$$

or

$$\lambda = E_f/C_f = E_a/C_a,$$

where the subscripts represent partial derivatives.

When availability is not believed to contribute to combat effectiveness the model becomes

$$\text{Max } \pounds = E(F) + \lambda[(C^{o} - C(F,A)]$$

and the solution is

$$\lambda C_{f} = E_{f}, \text{ and}$$
$$\lambda C_{a} = 0.$$

That is, we should pick F^{*} such that the marginal contribution of F to combat effectiveness is equal to λ times the marginal cost of F, but we should simply set A^{*} at the low point of its marginal cost curve. This implies that if that cost is composed of acquisition costs and support costs, then the preferred point for A is where marginal acquisition costs are equal to and of opposite sign to marginal support costs (see Fig. 1 in the text).

Talks with service personnel indicate that the latter model is used far too frequently. Minimizing the costs associated with a given level of functional performance is perhaps the predominant goal of operational and support organizations, and of most support-oriented personnel associated with program acquisition offices. This is unfortunate because *if availability contributes to combat effectiveness*, as we certainly believe it does, *selecting the level of availability that minimizes (marginal) support costs typically yields too little availability and less combat effectiveness than the budget allows.* This can be seen in Fig. A.1. If, in attempting to save money, we back off from A^{*} (to, for example, the point X), we are necessarily moving to a lower level of E.

Appendix B

BRIEF DESCRIPTIONS OF THE OLDER WARRANTIES

THE C-17 AIR VEHICLE

Section H of the C-17 development contract (F33657-81-C-2108) negotiated with the Douglas Aircraft Company in 1981 contains (a) a warranty of contractual specification conformation, design integration, and material and workmanship; (b) a warranty of fleet reliability, maintainability, and availability; (c) a warranty for the installation of parts; and (d) a warranty of design information.[1]

The remedies for the (a) and (b) warranty clauses include correction, repair, rework, replacement, or redesign; for (b) in particular this includes changes in the design and production procedures for all aircraft in production or still to be produced and retrofit of those (up to 16) already delivered; for (c) it includes reinstallation and the assumption of the parts vendor's warranty; and for (d) the correction of the information and the repair, rework, or replacement of any damage it caused.

Defects must be discovered no later than 180 days after initial operational capability, which is defined as the delivery of 12 production-configured aircraft and their supporting equipment and data. The basis for the incentive fee for availability, reliability, and maintainability achievement will be a highly structured 30-day mini-squadron evaluation that is scheduled to take place in the early 1990s.

THE DSCS-II AND DSCS-II COMMUNICATION SATELLITES

The Defense Satellite Communications System is an evolutionary DoD system designed to provide 8/7 GHz satellite communication for secure voice and data transmission.[2] DSCS-II development began in 1969 under

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[1]This discussion of the C-17 air vehicle program and warranty is based on several visits to the C-17 program office and to the Douglas Aircraft Company during 1984 and 1985.

[2]This discussion of the DSCS programs is taken from Ref. 16.

contract F04701-69-C-0091 with the TRW Corporation and eventually resulted in the purchase of a total of 16 flight spacecraft and associated support equipment, the final 12 spacecraft being purchased under contract F04701-74-C-0450.

In 1977 the Air Force signed an FPI contract (F04701-77-C-0036) with General Dynamics for the FSD of next-generation DSCS-III spacecraft. Two additional contracts (F04701-80-C-0058 and F04701-81-C-0004) soon increased the buy to a (current) total of seven spacecraft.

The production incentives under all of these contracts are contingent on the successful operation of the communication mission of the satellites and are designed to encourage development and manufacturing practices that increase the probability the satellites will operate successfully throughout their designed life.

DSCS-II and early DSCS-III incentive payments are both positive (giving the contractor bonus money for each period that the satellite operates successfully up to its designed lifetime) and negative (the contractor pays the Air Force a penalty for each period the satellite fails to operate successfully).

The latest DSCS-III incentives provide only for penalties if the satellites perform less than satisfactorily. The importance of the DSCS performance incentives has decreased steadily, until now complete and immediate failure of a satellite will result in only a 7 percent reduction in its purchase price.

THE F-16 AVIONICS LRUS

The F-16 RIW contract F33657-77-C-0062 was signed on February 3, 1977, for an apparent original price of $30,460,755 then-year dollars.[3] The contract provided for an RIW on seven avionics LRUs and an RIW with MTBF guarantee on two additional units. Those LRUs were installed on some 250 USAF and 192 European F-16As and F-16Bs. General Dynamics was

[3]This discussion of the F-16 avionics warranties is taken from contractual documents and from Ref. 10.

the prime contractor for the warranty but the four individual suppliers were required to furnish the repair, redesign, and support work. The involved LRUs are listed Table B.1.

The RIW provided that each failed LRU would be sent to the seller's facility where he would repair or replace it (within 22 days or provide extra spares). The RIW covered 48 months or a total of 300,000 fleet flying hours, whichever came first.

The MTBF guarantee provided that the reliability performance of the LRUs would be computed for each six-month period over three years, and whenever the measured MTBF was less than the target MTBF specified in the contract the seller would furnish at no additional cost to the government: (a) engineering change analysis, (b) corrective engineering design changes, (c) modification of the units, and (d) pipeline unit spares. If the target MTBF was met or exceeded for two consecutive periods, however, the contractor's obligation was terminated. Despite some initial problems the MTBF goals for both LRUs were achieved before the end of the contractual warranty period and the guarantee was terminated.

Table B.1

WARRANTIES FOR F-16 LRUs

Warranty and LRU	LRU Contractor
RIW only	
Flight control computer	Lear-Siegler Industries
Radar antenna	Westinghouse Electric Corporation
Radar low power RF	Westinghouse Electric Corporation
Radar digital signal processor	Westinghouse Electric Corporation
Radar computer	Westinghouse Electric Corporation
Head up display pilot display	Marconi Avionics, Ltd.
Inertial navigation unit	Singer-Kearfott Division
RIW and MTBF Guarantee	
Radar transmitter	Westinghouse Electric Corporation
Head up display processor	Marconi Avionics, Ltd.

A report, prepared by the ARINC Research Corporation mid-way through the warranty period, stated somewhat ambiguously:

> Based on an interim evaluation, ARINC Research concludes that the F-16 RIW program has been beneficial to date. The government and all the contractors will most likely benefit financially from the program. Reliability levels of both warranted and nonwarranted equipments are acceptable in terms of original SPO expectations; no outstanding reliability gains were observed for the warranted equipment. Despite protracted litigation, which has not been resolved, the program has been successfully implemented without any other major problems. One negative aspect--which provides an important lesson to be learned--is the deterrent to subcontractor motivation engendered by the prime contractor-subcontractor arrangements embodied in this RIW program [10, p. ix].

There was no follow-on evaluation conducted at the end of the warranty period.

THE F109 ENGINE

Contract F33657-82-C-2129 for the warranty of F109-GA-100 engines for the T-46 aircraft was negotiated with the Garrett Turbine Engine Company in 1982. It calls for each engine to be free from defects in material and workmanship, and in integration, installation, modification or other work for 360 days from the date of delivery. It also wa.ranted that for 1000 engine flight hours (EFHs) or two years each engine will be serviceable per specifications, the hot-gas flowpath items of the combustor and turbine zones will remain serviceable with scheduled maintenance, and the engine turbine inlet temperature will not deteriorate to below specifications.

If any of the above occur, Garrett will repair or replace the suspect parts or engines or they will pay the government for its doing so. Delivery of these engines is just beginning, so evaluation of the warranty provisions will begin in several years.

THE ARN-118 TACAN

The Collins Radio Group of Rockwell International sold the ARN-118 TACAN to both the Air Force and the Navy under F19628-75-C-0144 beginning in July of 1975.[4] This contract was procured competitively with both an RIW and an MTBF guarantee and is alleged to be the first major acquisition with a RIW.

The RIW called for Collins to ship a replacement unit within 24 hours of being notified of a failure. ECPs were encouraged but could be disapproved by the government; if approved then the contractor must incorporate them into all items, both previously delivered and still to be produced, at no additional cost to the government. Between June 1975 and April 1982 some 10,000 TACANs were covered.

The MTBF goals increased with time from 500 hours to 800 hours. If they were not met Collins had to analyze the problem, implement (no-cost) design changes, and provide additional pipeline spares.

In May of 1982 Headquarters AFLC evaluated this warranty and concluded that

> The AN/ARC-118 TACAN RIW was successful in motivating the contractor to significantly enhance the reliability of the TACAN. However, government fulfillment of its contractual obligations or lack thereof caused serious impacts to the program which may have diluted the overall benefits [17].

The government-generated problems included incomplete recording of operating data (hours), unauthorized government handling of warrantied items, and an excessive number of return units that retested OK. Collins is said to have recognized these same problems but, in general, also to have viewed the program as successful. The government contends that Collins implemented between 300 and 400 design change notices during the warranty period, resulting in "creeping configuration change" for which the government lacked documentation [18].

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[4]This discussion of the AN/ARN-118 TACAN RIW is based on documents provided by the Air Force Electronic Systems Division and by Headquarters Air Force Logistics Command.

THE CAROUSEL INS

The Warner-Robbins Air Logistic Center contracted with Delco Electronics on 14 November 1975 for up to 1,073 Carousel IV inertial navigation systems.[5] Delco had been providing the Carousel INS to several commercial airlines before the Air Force contract, and it had been performing at a 750 hour MTBF in the commercial environment. The Air Force procurement was essentially an off-the-shelf procurement of the commercial set.

The Air Force warranty required a system MTBF of 1,128 hours and is said to have actually achieved some 1,313 hours MTBF during the RIW period. Thus, the reliability of the Air Force units was substantially greater than that of the commercial units even though the Air Force systems were probably operating in a more stressful environment.

THE LN-39 INU

The warranty between the Air Force and Litton Guidance and Control Systems for the LN-39 inertial navigation unit (INU) was executed on January 30, 1980.[6] It covered 378 A-10 aircraft and 37 F-16 aircraft and covered the period from 20 April 1981 to 20 April 1986.

The stated objectives of the warranty were:

a. to induce the contractor to design reliability and maintainability into the INU

b. to insure the USAF INU met the MTBF and turnaround time requirements of the production contract:

   i. average turnaround time of 22 days, and

   ii. MTBF growth to 525 hours at the end of five years (April '86);

c. to require no-cost ECPs when the MTBF requirements were not met

d. to provide consignment spares and/or equivalent dollars when the turnaround time requirement was not met and

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[5] This discussion is taken from Ref. 12, pp. 31-34.

[6] Material on the LN-39 INU warranty was provided by Litton Guidance and Control Systems.

e. to require modification kits at the end of the warranty period, at no additional cost to the government, for all INUs not in the latest approved configuration.

Litton reports some troubles with this warranty. In particular, there have been problems with the built-in test equipment on the INU. Many LRUs give failure indications but then retest OK (RTOK) when removed from the aircraft and returned to Litton. Because the warranty says that all RTOKs in excess of 5 percent are counted as true failures and the RTOK rates often ran considerably higher, the MTBF targets have not been met. Litton has developed many ECPs for the built in test and succeeded in lowering the rate slightly. Litton contends, however, that the main problem is uncontrolled variations in the power supplied to the INU by other components.

Despite the lower than expected MTBF the government feels the warranty is worthwhile because of the ECPs and spares that have been provided at no cost by the contractor.[7]

THE LN-35 INES

Beginning with contract N00019-81-C-3113 Litton Guidance and Control provided both an RIW and an availability guarantee for the LN-35 inertial navigation elements it provided for the AGM-86B Air Launched Cruise Missile.[8] The RIW (with MTBF guarantee) was similar to that described above for the LN-39; the availability guarantee provided that certain numbers of tests and test firing be successful. The warranties covered all INEs delivered from the execution date of the contract through its expiration date of December 31, 1986. Thus some INEs may have been warrantied for only several months.

The ALCM availability guarantee provision required an availability growth on production units from 91 percent in the first measurement

[7]See Ref. 12, pp. 39-42.

[8]Material on the LN-35 INU warranty was obtained from Litton Guidance and Control Systems and from the Product Performance Agreement Center.

period (November '81 to December '82) to 96 percent in the fifth measurement period (January '86 to December '86). Litton has objected to the specification of this provision contending that the specified computational procedures and the small number of tests require perfect performance of the INEs to meet even the 91 percent requirement.

In July of 1985 the Air Force commented on this warranty:

> The ALCM INE, as of 31 December 1984, was performing better than required by the RIW/AG. The MTBF was 760 hours versus the 356 hours required between January 1984 and December 1984; the effective availability was 98.9 percent versus an effective availability requirement of 96 percent; and a no-cost-to-the-Government ECP was incorporated to correct an ordnance monitor loop deficiency. According to actual data for repair of six LN-35 production INEs (which were exclusions to the warranty provision) the average cost of repair was almost $25,000. This results in a difference of $8,900 per unit for the intangible benefits occurring under the entire warranty. HQ AFSC considers the $8,900 as an equitable cost for the intangible benefits. On the basis of the performance achieved, the ALCM INE RIW/AG is judged to be effective. It is premature, though, to draw a firm conclusion on its cost effectiveness. A final evaluation should be done at the conclusion of the warranty which runs until December 1986 [12, pp. 47-48].

THE APG-68 RADAR FOR THE F-16

Contract F33657-81-C-0641 with the Westinghouse Electric Company contains four types of incentives, two of which are performance incentives. We consider those as the performance warranty. This APG-68 radar reliability performance "warranty" is a rather involved incentive arrangement.[9] First, there are two potential award fees, which we will not consider as part of the warranty. One was set for January of 1983 (when WEC received $225,000 of a possible $250,000) and the other for January of 1984 (when WEC received none of a maximum $250,000). Then the "warranty" begins. First, the four LRUs under warranty must pass their production reliability qualification test and establish minimum mean time between maintenance actions (MTBMAs) before they can qualify

[9] This discussion of the APG-66 radar is based primarily on material and discussions with personnel from PPAC and from the Air Force Aeronautical Systems Division.

for any warranty incentive. Then the warranty incentives involve only bonus arrangements and cover two periods: the first 9-month field reliability measurement was to run from May 1985 to January 1986 (maximum incentive of $11.9 million); the second was originally scheduled to run from August 1988 to January 1989 (maximum incentive of $6.7 million).

The incentives are structured so that the contractor has an incentive to improve the performance of the radar from a basic level of 27.9 hour Type 1 MTBMA. There is no contractual penalty other than normal contractual recourse if he fails to achieve this level of performance. Because the incentive is only positive, the contractor can stop all his efforts for improvement if he believes that they are unobtainable. Of course, his reputation will suffer and he could expect some loss in his business base if he fails.

As suggested above the performance of this system is apparently not as satisfactory as the program office and the contractor had hoped, but we have no late word on the status of the warranty.

THE TF34 ENGINE FOR THE A-10 AIRCRAFT

The TF34 engine for the A-10 aircraft was one of the first engines to have a warranty.[10] This warranty came about because of the need to limit exposure after the early F100 experience. The objective was "quality in production." The San Antonio Air Logistics Center has data to show the failure rate went down, but whether the decline was due to the warranty or to a continuing component improvement program is unknown. The warranty covers any failure when a part did not meet Table of Operation or specifications for 1,000 hours. The costs for the first year for one lot was $4 million. The engine project officers believed that this warranty improved the production quality control process and motivated GE to make changes more rapidly. However, the SPO also spent many millions on the CIP program.

[10]The discussions of this and the following engine warranties are all based primarily on discussions with Dr. Robert Dean and his colleagues at the Propulsion program office as ASD and with Major Kenneth Roberts of the Contract Law Center as ASD.

THE F100 ENGINE FOR THE F-15 AND F-16 AIRCRAFT

The first F100 engine warranty was signed in 1979. Since then they have signed new warranties each year when a new production lot is contracted for. The warranty improves each year because both the Air Force and the contractor believe they know a little more (both about warranties and about the engines). The initial F100 warranty was very limited, covering only 100 engine flight hours. The more recent warranties contain the following items:

- A supply warranty covering defects in material and workmanship for 240 days following DD250
- An expanded 200 hour Total Operating Time or two year warranty
- A high-pressure turbine warranty for 42 months or 900 tactical cycles, under some conditions upgradable to 60 months or 1650 cycles
- A fan disk warranty for ten years or 3,000 tactical cycles
- A delivery support warranty.

The Propulsion SPO personnel contend that their current engine warranties perform four primary functions:

1. Protect the Air Force against "lemons" entering the field
2. Provide maintenance support for (possibly numerous) early failures
3. Induce increased quality control discipline at the contractor's plant
4. Provide the contractor with maintenance information and feedback

It is too early to tell how these engine warranties are working out. Although many of them were written years ago, most of the engines have not been delivered yet or accumulated enough flight hours.

To achieve the benefits promised by warranties, future designs will have to include devices that record operating times and performance. Engines will require diagnostic systems to insure that pilots do not inadvertently operate the engine near the envelope limits and then fail to report them. This is currently a situation that causes problems for the depot and must be corrected or at least monitored for engines under warranty.

THE F108 ENGINE FOR THE KC-135 AIRCRAFT

The warranty for the F108 engine (CFM56), used on the re-engined KC-135, is described as a "commercial warranty." This apparently means that it was proposed by the supplier rather than the Service, and accepted by the Service without substantial change. The costs associated with the warranty are included in the overall price of the engine and are not clearly identifiable. This technique is apparently similar to the warranty pricing policies used by airlines.

There are three parts to the warranty:

- Part I warrants the engines for parts and [illegible] less, [illegible] engine flight hours, or [illegible] years, whichever is less.
- Part II warrants approximately [illegible] tracked parts [illegible] for parts cost only. This warranty [illegible] months or [illegible] flight hours, whichever is less.
- Part III provides bonus or penalty arrangements for the shop-visit rate, the in-flight shut-down rate, and [illegible] engine removals because of excess exhaust gas temperature.

The [illegible] is not in service yet, but the warranties were negotiated sometime after the design had been finalized.

THE F110 AND F220 ALTERNATIVE FIGHTER ENGINES

The Alternative Fighter Engine, for use in F-15s, F-16s, and some F-14s, is currently being procured under an initial production contract signed in [illegible]. Special language in the DoD Appropriation Act for that year required the AFE warranty. Since the 1985 and 1986 buys are still under options written into the [illegible] contract, the original warranty applies.[11]

[11]The 1985 warranty law applies only to acquisition contracts signed after January 1, 1985.

The Air Force warranty, for engines for the F-15s and F-16s, is in three parts:

> Part I warrants the engines, modules, components, tracked parts, and support equipment against defects in material and workmanship and warrants them to be serviceable within T.O. limits for about three years (sometimes expressed as three years, sometimes as 1,000 effective engine hours, sometimes as as 3,000 tactical cycles, and sometimes the lesser of some combination of these).[12]
>
> Part II warrants the combustor and the high pressure turbine for eight years or 3,000 TACs. As with Part I the contractor will repair or replace any and all failed engines and parts or will pay the Air Force for so doing.
>
> Part III provides bonus/penalty arrangements for scheduled and unscheduled engine removal rates measured over 6-month periods between 1989 and 1995.

Engine deliveries were scheduled to begin in 1986.

THE AN/ASN-92 INS WARRANTY

The Litton AN/ASN-92 inertial navigation system has been the standard navigation system on several Navy aircraft (F-14, A-[illegible] [illegible] S-3A, TC-4C, and RF-4B) for many years and has in fact [illegible] as CAINS, the carrier aircraft INS.[13] In 1980 the Navy contracted for wide-ranging support of this system [illegible] called the CROWN (CAINS Reliability and Oper[illegible] [illegible] Navy) program. This program, among other [illegible] the AN/ANS-92 INS.

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[12]Tactical or total accumulated [illegible] as a combination of throttle m[illegible] fatigue, a full throttle cycle, [illegible]

[13]This discussion of the [illegible] on material and dis[illegible] 20.

AD-A185 292 WARRANTIES FOR WEAPONS: THEORY AND INITIAL ASSESSMENT 2/2
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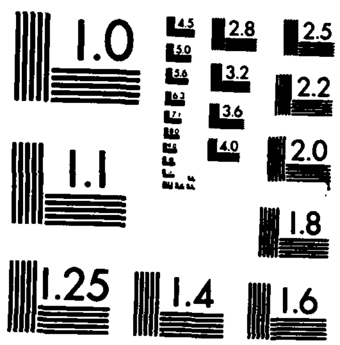

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

The fixed-price contract was for 1,225,000 flight hours (about five years) beginning in 1980. Whenever a warranted LRU fails Litton must respond by getting a replacement into the pipeline within 24 hours. And because Litton performs all depot maintenance on failed LRUs or shop-replacable units, it is obviously in their interest to keep improving product reliability and maintainability. Whenever the required turnaround time is not met, Litton is docked one flight hour per day per item.

> The CROWN contract for support of the AN/ASN-92 has been in effect for twenty-five months. At this juncture, a profound improvement has been realized in the fleet availability of the AN/ASN-92 assets. Consequently, the readiness of the AN/ASN-92 in the operational fleet has also been tremendously improved. The bottom line is that the CROWN is a success and will be instrumental in retaining the welfare of the AN/ASN-92 within the Navy [19, p. 4].

THE APN-227 RADAR FOR THE P-3C AIRCRAFT

The P-3C doppler navigation radar maintenance and repair agreement was signed between the U.S. Navy (the user), Lockheed-California Company (the contractor), and Canadian-Marconi Company (the supplier in the early 1980s).[14] Essentially, for a fixed fee Marconi agreed to perform both intermediate and depot maintenance for all radar units for five years after they were introduced into the field. This was a simple maintenance and repair agreement, but it involved the repair of operational items under a fixed-price contract so it meets all our qualifications for a "warranty."

This program is apparently nearing or at the end of its five-year period and there is some question on whether to renew the maintenance and repair agreement. The original MTBF targets--on which the maintenance and repair agreement price was determined, the user's spares were procured, and the user's operational schedule was based--have apparently been surpassed, and there seems to have been no major troubles with turnaround times or with the need for costly ECPs. Hence, all parties contend the program is a success.

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[14]This discussion of the APN-227 Radar maintenance and repair agreement is based on material obtained from the PPAC, especially Ref. 21.

Appendix C

IDENTIFICATION OF 1985 LAW WARRANTIES

This appendix identifies the programs and warranties included in Table 3. The entries are mostly self-explanatory except for the time period notation. That includes:

0 indicates coverage stops with the acceptance of the product.
1 indicates coverage extends for 1 year or less after delivery/acceptance.
M indicates the coverage extends for longer than 1 year.

SINCGARS
Airborne, anti-jam, VHF AM/FM radio compatible with the Army frequency hopping, VHF radio
Product division: Electronics Systems Division
Contractor: Cincinnati Electronics Corporation
Contract number: F19628-85-C-0086 — Date signed: 7/2/85
Status of program: full-scale development — Years covered: M

NAVSTAR User Equipment
User equipment which receives satellite data and provides 3-dimensional position, velocity, and time information.
Product division: Space Division
Contractor: Rockwell-Collins
Contract number: F04701-85-C-0038 — Date signed: 4/1/85
Status of program: initial production — Years covered: M

SCPS-2
Survivable collective protection system to protect personnel from the effects of chemical and conventional warfare attacks.
Product division: Aeronautical Systems Division
Contractor: BMY, a division of HARSCO Corporation
Contract number: F33657-85-C-0079 — Date signed: 9/13/85
Status of program: initial production — Years covered: 1

STD PA INU
Precision accuracy (0.2nm/hr cep) inertial navigation unit for multiple aircraft application.
Product division: Aeronautical Systems Division
Contractor: Kearfott Division of Singer Company
Contract number: F33657-85-C-0056 — Date signed: 9/30/85
Status of program: initial production — Years covered: 5

SCDAC
Standard (digital) central air data computer to replace existing electro-mechanical analog Air Force and Navy airborne data computers.
Product division: Aeronautical Systems Division
Contractor: GEC Avionics Limited
Contract number: F33657-85-C-0025 Date signed: 6/21/85
Status of program: initial production Years covered: 3

STD AND F-15 RLG INU
Standard medium accuracy (0.8 nm/hr cep) inertial navigation unit for multiple aircraft.
Product division: Aeronautical Systems Division
Contractor: Litton Systems, Inc.
Contract number: F33657-85-C-2158 Date signed: 8/9/85
Status of program: initial production Years covered: 5

F100 ENGINES
F100-PW-220 engines for use in 159 USAF and FMS F-15 and F-16 aircraft.
Product division: Aeronautical Systems Division
Contractor: Pratt & Whitney
Contract number: F33657-84-C-2014 Date signed: 2/3/85
Status of program: initial production Years covered: 3

MX SUPPORT EQUIPMENT
Peacekeeper support equipment
Product division: Ballistic Missile Division
Contractor: Martin Marietta
Contract number: F04704-85-C-0064 Date signed: 8/13/85
Status of program: initial production Years covered: 4

MX OPERATIONAL SUPPORT EQUIP
Peacekeeper basing operational support equipment
Product division: Ballistic Missile Division
Contractor: Boeing Aerospace Company
Contract number: F04704-85-C-0050 Date signed: 10/17/85
Status of program: initial production Years covered: 5

EWWS UPDATE
Electronic warfare equipment upgrade.
Product division: Aeronautical Systems Division
Contractor: Magnavox
Contract number: F33657-85-C-0383 Date signed: 10/23/85
Status of program: follow-on production Years covered: 0

F-15
This is the 1985 buy of the F-15 fighter aircraft
Product division: Aeronautical Systems Division
Contractor: McDonnell Douglas
Contract number: F33657-85-C-2086 Date signed: 7/29/85
Status of program: follow-on production Years covered: 1

MHU 196
Mobile handling units (trailers and support equipment).
Product division: Aeronautical Systems Division
Contractor: AAI Corporation
Contract number: F33657-84-C-0235 Date signed: 4/22/85
Status of program: follow-on production Years covered: 1

TR-1/U-2R AIRCRAFT
Continued production of the U-2 with super pods.
Product division: Aeronautical Systems Division
Contractor: Lockheed Corporation
Contract number: F33657-84-C-0181 Date signed: 7/10/85
Status of program: follow-on production Years covered: 1

AGM-65D MAVERICK MISSILE
AGM-65D imaging infrared Maverick missile.
Product division: Aeronautical Systems Division
Contractor: Hughes Aircraft Company
Contract number: F33657-84-C-2220 Date signed: 3/29/85
Status of program: follow-on production Years covered: 3

MX TGG
Peacekeeper third-generation gyro
Contractor: Honeywell
Contract number: F04704-85-C-0077 Date signed: 6/28/85
Status of program: follow-on production Years covered: M

MX STAGE I AND FTOS
Peacekeeper first stage and flight termination ordinance system.
Product division: Ballistic Missile Division
Contractor: Morton Thiokol, Inc.
Contract number: F04704-85-C-0021 Date signed: 8/26/85
Status of program: follow-on production Years covered: 5

MX STAGE III
Peacekeeper third stage.
Product division: Ballistic Missile Division
Contractor: Hercules
Contract number: F04704-85-C-0023 Date signed: 9/9/85
Status of program: follow-on production Years covered: 5

MX ORDNANCE INITIATION SYSTEM
Peacekeeper ordnance initiation system.
Product division: Ballistic Missile Division
Contractor: Lockheed Missiles & Space Company
Contract number: F04704-85-C-0020 Date signed: 7/31/85
Status of program: follow-on production Years covered: 5

REFERENCES

1. B. J. Allen, R. L. Bardenstein, and A. L. Fritz, *Product Performance Agreement Decision Support Handbook*, TR-4632-2R, The Analytic Sciences Corporation, February 1985.

2. H. S. Balaban, K. B. Tom, and G. T. Harrison, Jr., *Warranty Handbook*, ARINC Research Corporation, June 1986.

3. U.S. Air Force, *ESD System Readiness Engineering Handbook* Headquarters Electronics Systems Division, AFSC, April 1986.

4. J. M. Cummings, "Incentive Contracting for National Defense: A Problem of Optimal Risk Sharing," *Bell Journal of Economics*, Vol. 8 (1977), pp. 168-185.

5. A. Gandara and M. D. Rich, *Reliability Improvement Warranties for Military Procurement*, The RAND Corporation, R-2264-AF, December 1977.

6. F. M. Scherer, "The Theory of Contractual Incentives for Cost Reduction," *Quarterly Journal of Economics*, Vol. 78 (1964), pp. 257-280.

7. R. B. Bardenstein, D. R. Czech, S. G. Dizek, G. B. Dunphy, and A. L. Fritz, *Product Performance Agreement Center Year One Final Technical Report*, TR-4621-1R, The Analytic Sciences Corporation (updated) February 1985.

8. Title 10, Section 2403 of the United States Code.

9. Public Law 98-212, Sec. 794, a.1.

10. F. Crum, R. Gilbertson, and G. Harrison, *An Interim Evaluation of the F-16 Reliability Improvement Warranty Program*, Final Engineering Report 1565-11-2-2527, ARINC Research Corporation, September 1981.

11. D. R. Czech, *Product Performance Agreement Center Year Two Final Technical Report*, The Analytic Sciences Corporation, December 1984.

12. M. A. Guenther (Lt. Col. USAF), *Assessment of the Reliability Improvement Warranty*, Air Force Product Performance Agreement Center, Wright-Patterson AFB, July 12, 1985.

13. R. Hubbard (Major USAF), *Reliability Improvement Warranty Aspects of the AN/ARN-118 TACAN Program*, The Air University, Maxwell AFB, April 1978.

14. K. B. Tom, E. E. Ayers, and H. S. Balaban, *Analysis of Warranty Cost Methodologies*, Technical Report 3243-01-TR-3504, ARINC Research Corporation, January 1985.

15. Seki Choo, *Warranty Model User's Guide,* U.S. Army Aviation Systems Command, USAAVSCOM TR-85-F-6, St. Louis, July 1985.

16. G. K. Smith, J. P. Stucker, and E. J. Simmons, *Commercial and Military Communication Satellite Acquisition Practices*, The RAND Corporation, R-3121-AF, May 1985.

17. J. E. Aceto, "Limited Evaluation of the AN/ARN-118 TACAN Reliability Improvement Warranty," letter to ESD/TOP dated May 27, 1982.

18. *Limited Evaluation of the AN/ARN-118 TACAN Reliability Improvement Warranty*, letter from J. E. Aceto, Chief, Initial Acquisition Support Branch, DCS/Logistics Operations, to ESD/TOP, dated May 27, 1982.

19. J. P. McHale, and L. R. Brown, *CROWN--the Navy's Solution to Fleet Readiness Problems and Conventional Inertial Navigation Systems*, Naval Air Systems Command, paper presented to the Joint Services Data Exchange for Inertial Systems, November 17, 1982, p. 4.

20. T. R. Sturm, "CROWN--Prince of the RIW Programs," *Military Electronics/Countermeasures*, December 1980, pp. 30-39.

21. R. F. Steiner (Lockheed-California) and M. Gordon-Smith (Canadian-Marconi), *P-3C Doppler Navigation Radar Maintenance and Repair Agreement: A Win-Win Success Story*, briefing charts and supporting material, n.d.

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